Beiträge zur Anforderungsanalyse im Rahmen der Entwicklung betrieblicher Anwendungssysteme aus Sicht der Wirtschaftsinformatik

Dissertation

der Wirtschaftswissenschaftlichen Fakultät

der Universität Augsburg

zur Erlangung des Grades eines Doktors

der Wirtschaftswissenschaften

(Dr. rer. pol.)

vorgelegt

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Augsburg, September 2009

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Datum der mündlichen Prüfung:	22. Oktober 2009

„Die Wissenschaft […] ist im wesentlichen eine im Wachsen begriffene Erscheinung;
sie ist wesentlich dynamisch, ist niemals etwas Fertiges:
Es gibt keinen Punkt, an dem sie endgültig ihr Ziel findet.“

Karl R. Popper (1994)
(aus: Alles Leben ist Problemlösen, Piper, München, S. 34)

Inhaltsverzeichnis

Anmerkung: Eine fortlaufende Seitennummerierung wird pro Kapitel beziehungsweise pro Unterkapitel des jeweiligen Beitrags vorgenommen. Ein Literaturverzeichnis sowie die Anhänge werden jeweils am Ende eines jeden Beitrags aufgeführt.

Verzeichnis der Beiträge

In dieser Dissertation werden die folgenden veröffentlichten und zur Veröffentlichung angenommenen Beiträge vorgestellt:

B.1 Röglinger M (2009) Verification of web service compositions: An operationalization of correctness and a framework for service-oriented modeling techniques. Business & Information Systems Engineering 1(6) (in Druck) (VHB-JOURQUAL2 7,3 Punkte; Kategorie B)

B.2 Röglinger M, Reinwald D, Meier MC (2009) Ein formaler Ansatz zur Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge. In: Hansen HR, Karagiannis D, Fill HG (Hrsg) Wirtschaftsinformatik 2009 - Business Services: Konzepte, Technologien, Anwendungen (Band 2), Wien (VHB-JOURQUAL2 6,7 Punkte; Kategorie C)

B.3 Röglinger M (2009) How to select measures for decision support systems – An optimization approach integrating informational and economic objectives. In: Proceedings of the 17th European Conference on Information Systems, Verona (VHB-JOURQUAL2 7,3 Punkte; Kategorie B)

B.4 Kamprath N, Röglinger M (2009) An organizational perspective on critical success factors for customer relationship systems – A descriptive case study. In: Proceedings of the 15th Americas Conference on Information Systems, San Francisco (VHB-JOURQUAL2 5,9; Kategorie D)

I Einleitung

Gegenstand der Wirtschaftsinformatik sind Informations- und Kommunikationssysteme in Wirtschaft und Verwaltung – kurz: betriebliche Informationssysteme (Wissenschaftliche Kommission Wirtschaftsinformatik 1994, S. 80). Unter einem Informationssystem versteht man ein System, das Informationen verarbeitet, d. h. erfasst, überträgt, transportiert, speichert und bereitstellt (Ferstl und Sinz 2006, S. 1). Ein betriebliches Informationssystem ist ein Informationssystem, das Aufgaben im Rahmen einer an den Unternehmenszielen ausgerichteten Steuerung der betrieblichen Leistungserstellung und der Erstellung informationsbasierter Dienstleistungen übernimmt (Ferstl und Sinz 2006, S. 2). Diese üblicherweise vernetzten Aufgaben werden kooperativ und – je nach Automatisierbarkeit – exklusiv bzw. anteilig von personellen und maschinellen Aufgabenträgern durchgeführt. Nichtautomatisierbare Aufgaben (z. B. solche mit hohem Kreativitätsanteil, niedrigem Strukturierungsgrad, geringer Repetitivität oder Erfordernis menschlicher Interaktion) werden idealtypisch personellen Aufgabenträgern (z. B. Sachbearbeitern, Datenerfassern, Führungskräften) zugeordnet. Automatisierbare Aufgaben (z. B. solche mit hoher Repetitivität, hohem Strukturierungsgrad oder formal spezifizierbarem Lösungsverfahren) werden maschinellen Aufgabenträgern zugeordnet. Darunter versteht man in der Wirtschaftsinformatik insbes. betriebliche Anwendungssysteme, welche die Lösungsverfahren automatisierbarer Aufgaben – also deren fachliche Funktionalität – auf Basis geeigneter Systemsoftware, Hard- und Middleware realisieren (Ferstl und Sinz 2006, S. 444). Aufgrund der konstruktions- und ingenieurwissenschaftlichen Tradition der deutschsprachigen Wirtschaftsinformatik (Wilde und Hess 2007, S. 280; Frank et al. 2008, S. 391) kommt der Entwicklung betrieblicher Anwendungssysteme[1] eine zentrale Bedeutung zu (Wissenschaftliche Kommission Wirtschaftsinformatik 1994, S. 81; Mertens et al. 2005, S. 3; Grochla 1969). Dies wird u. a. durch eine von Hasenkamp und Stahlknecht (2009, S. 24) durchgeführte Inhaltsanalyse der Zeitschrift WIRTSCHAFTS-INFORMATIK als dem zentralen Organ der deutschsprachigen Wirtschaftsinformatik-Community gestützt.

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[1] Synonym verwandte und im deutschen Sprachraum gebräuchliche Begriffe sind u. a. Systementwicklung (Ferstl und Sinz 2006), Software Engineering (Sommerville 2004), Software-Entwicklung (Balzert 1998).

Als grundlegendes methodisches Hilfsmittel der Entwicklung betrieblicher Anwendungssysteme haben sich u. a. phasenorientierte Vorgehensmodelle etabliert. Dazu gehören z. B. das Wasserfallmodell (Royce 1987), das Spiralmodell (Boehm 1988), das Prototyping, das V-Modell (Der Beauftragte der Bundesregierung für Informationstechnik 2009), das eXtreme Programming (Beck und Andres 2004) und der Rational Unified Process (Kruchten 2003). Vorgehensmodelle weisen spezifische Vor- und Nachteile auf. Zudem unterscheiden sie sich dahingehend, ob in jeder Phase das gesamte zu entwickelnde Anwendungssystem oder nur ein Teil bearbeitet wird (holistisch vs. inkrementell) bzw. ob die Phasen einmal oder mehrmals durchlaufen werden (sequenziell vs. iterativ). Den meisten Vorgehensmodellen ist gemein, dass sie auf denselben bzw. sehr ähnlichen Phasen beruhen. Diese sind Projektplanung, Anforderungsanalyse, Softwareentwurf, Realisierung (inkl. Testen) sowie Abnahme und Einführung. Hinzu kommen Querschnittsaufgaben wie z. B. Projekt- und Qualitätsmanagement. Detaillierte Ausführungen finden sich z. B. in Ferstl und Sinz (2006), Sommerville (2004) oder Balzert (1998). Abb. I-1 zeigt die Phasen und ihre grundsätzlichen Reihenfolgebeziehungen vereinfachend als Kaskade im Sinne des Wasserfallmodells. In einer Interdisziplin wie der Wirtschaftsinformatik, die sich als Vermittlerin zwischen Betriebswirtschaftslehre und Informatik – also zwischen Fach- und IT-Seite – versteht, kommt der Anforderungsanalyse eine besondere Bedeutung zu. Zum einen weil man hier anstrebt, sämtliche fachlichen Anforderungen an das zu entwickelnde Anwendungssystem zu identifizieren und in Form eines Lastenhefts (Sommerville 2004) bzw. Fachkonzepts (Scheer 1991) als Grundlage für die weiteren Phasen eindeutig zu spezifizieren. Zum anderen weil hier der Übergang zwischen den fachlichen und softwaretechnischen Phasen der Anwendungssystementwicklung stattfindet. Daher setzen sich die in dieser Dissertationsschrift vorgestellten Beiträge mit der Anforderungsanalyse auseinander.

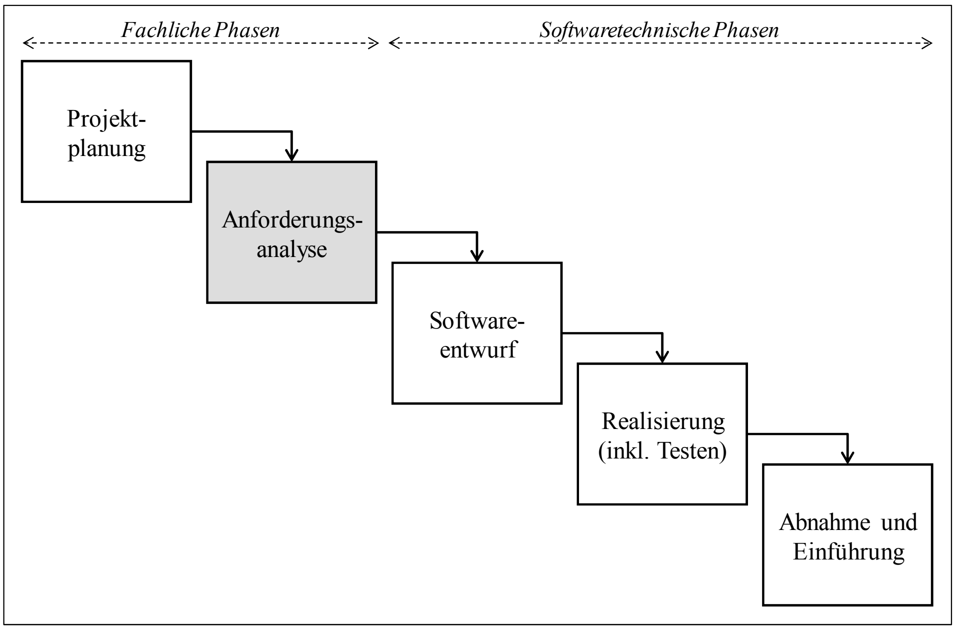

Abb. I-1 Phasen der Anwendungssystementwicklung (Ferstl und Sinz 2006, S. 463)

Es wird angenommen, dass die Identifikation und Dokumentation fachlicher Anforderungen stets systematisch und zielgerichtet zu erfolgen hat, die konkrete Vorgehensweise und deren methodische Unterstützung jedoch entsprechend der Klasse des zu entwickelnden Anwendungssystems anzupassen sind. Dabei lassen sich je nach Sichtweise unterschiedliche Anwendungssystemklassen abgrenzen. In einer wirtschaftsinformatisch bzw. fachlich geprägten Sichtweise unterscheidet z. B. Mertens (2005) Administrations- und Dispositionssysteme sowie Planungs- und Kontrollsysteme. Während erstere – die auch als operative Systeme bezeichnet werden – die Ziele Rationalisierung, Effizienz und Ressourcenschonung verfolgen, streben zweitere nach zielsicherer Planung und Kontrolle (Mertens et al. 2005, S. 4). In einer informatisch bzw. technisch geprägten Sichtweise lassen sich orthogonal dazu monolithische und verteilte Anwendungssysteme unterscheiden (siehe Abb. I-2). Diese Sichtweise ist zu berücksichtigen, da die Anforderungsanalyse den Übergang zu den softwaretechnischen und daher informatisch geprägten Phasen der Anwendungssystementwicklung darstellt. Monolithische Anwendungssysteme werden isoliert auf einem Rechner betrieben, verteilte Anwendungssysteme transparent für den Nutzer auf mehreren Rechnern (Coulouris et al. 2002, S. 17; Tanenbaum und van Steen 2003, S. 18). In der Praxis findet man kaum mehr isolierte Anwendungssysteme. Vielmehr tauschen Anwendungssysteme über Standort- und Unternehmensgrenzen hinweg Informationen aus, um gemeinsame betriebliche Aufgaben zu erfüllen. Auch in der Wissenschaft liegt der Schwerpunkt im Bereich der Anwendungssystementwicklung auf verteilten Systemen, nicht zuletzt weil der Integrationsgedanke seit jeher ein konstitutives Merkmal der Wirtschaftsinformatik ist (z. B. Kettner 1959). Wegen der geringen Bedeutung in Wissenschaft und Praxis werden monolithische Anwendungssysteme nicht weiter betrachtet. Zur Einordnung der vorgestellten Beiträge werden vereinfachend operative Systeme, Planungs- und Kontrollsysteme sowie verteilte Systeme unterschieden. Als Beispiel für operative Systeme dienen Customer Relationship Management-Systeme (CRM-Systeme). Als Beispiel für verteilte Systeme dienen Web Service-basierte Systeme.

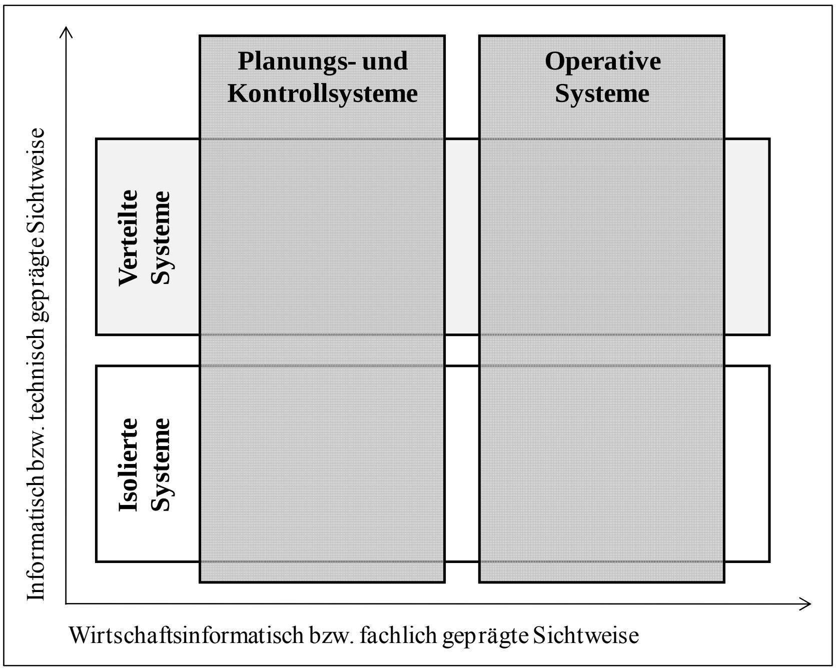

Abb. I-2 Anwendungssystemklassen nach einer wirtschaftsinformatisch bzw. informatisch geprägten Sichtweise auf Anwendungssysteme

Das verbleibende Kapitel gliedert sich wie folgt: In Abschnitt 1 werden die Zielsetzung und der Aufbau der Arbeit vorgestellt. In Abschnitt 2 werden die einzelnen Beiträge fachlich eingeordnet und die zentralen Forschungsfragen motiviert.

1 Zielsetzung und Aufbau dieser Dissertationsschrift

Ziel dieser Dissertationsschrift ist es, die Wissensbasis der Phase Anforderungsanalyse im Rahmen der Entwicklung betrieblicher Anwendungssysteme weiterzuentwickeln. Abb. I-3 strukturiert die verfolgten Ziele und zeigt den Aufbau der Arbeit.

I Einleitung

- Ziel I.1: Darstellung der Zielsetzung und des Aufbaus der Arbeit
- Ziel I.2: Fachliche Einordnung und Motivation der zentralen Forschungsfragen

II Anforderungsanalyse für verteilte Systeme – am Beispiel Web Service-basierter Systeme (Beitrag: „Verification of Web Service compositions: An Operationalization of Correctness and a Framework for Service-oriented Modeling Techniques“) (B.1)

- Ziel II.1: Konkretisierung des generischen Korrektheitsbegriffs der formalen Verifikation für Web Service Kompositionen
- Ziel II.2: Vorschlag eines Anforderungskatalogs für serviceorientierte Modellierungsansätze hinsichtlich deren Eignung zur Modellierung und Verifikation von Web Service Kompositionen
- Ziel II.3: Veranschaulichung der Anwendbarkeit des Anforderungskatalogs anhand eines ausgewählten serviceorientierten Modellierungsansatzes am Beispiel eines Web Service-basierten Kreditvergabeprozesses

III Anforderungsanalyse für Planungs- und Kontrollsysteme (B.2, B.3)

- Ziel III.1: Entwicklung eines Bewertungsschemas zur Quantifizierung des Nutzens von Kennzahlen
- Ziel III.2: Entwicklung eines quantitativen Optimierungsmodells zur Auswahl von Kennzahlen unter Berücksichtigung informationeller und ökonomischer Ziele
- Ziel III.3: Veranschaulichung des Einsatzes des Optimierungsmodells am Beispiel des Vertriebsbereichs eines Unternehmens der Elektronikbranche

IV Anforderungsanalyse für operative Systeme – am Beispiel von CRM-Systemen (Beitrag: „A multi-perspective analysis of operational critical success factors for customer relationship management – A descriptive case study“) (B.4) • Ziel IV.1: Fallstudienbasierte Identifikation von operativen CRM-Erfolgsfaktoren hinsichtlich der Perspektiven organisatorische Rahmenbedingungen, CRM-Prozesse und Informationsbedarf von Vertriebsbeauftragten • Ziel IV.2: Analyse von Gemeinsamkeiten und Unterschieden bez. operativer CRM-Erfolgsfaktoren im Produkt- und Lösungsvertrieb
V Fazit und Ausblick • Ziel V.1: Zusammenfassung der zentralen Ergebnisse • Ziel V.2: Aufzeigen künftigen Forschungsbedarfs

Abb. I-3 Aufbau der Dissertationsschrift

2 Fachliche Einordnung und fokussierte Forschungsfragen

Bezogen auf die Ziele werden nun die Beiträge fachlich eingeordnet und deren zentrale Forschungsfragen motiviert.

2.1 Anforderungsanalyse für verteilte Systeme – am Beispiel Web Service-basierter Systeme

Web Services und Web Service Kompositionen gelten als die am weitesten verbreiteten Technologien zur Implementierung von Serviceorientierten Architekturen (Erl 2004; Newcomer und Lomow 2005). Web Services stellen abgegrenzte Funktionalität über maschinenverarbeitbare Schnittstellen zur Verfügung. Web Service Kompositionen realisieren komplexere Funktionalität durch Koordination bestehender Web Services. Sie stellen ihre Funktionalität ebenfalls über Schnittstellen zur Verfügung (Alonso et al. 2004, S. 141). Gemäß einer Studie der Yankee Group wurden bereits im Jahr 2004 in mehr als 50 % der amerikanischen Unternehmen Web Services eingesetzt (Kallus 2004). Man erwartete sich insbes. eine verbesserte Unterstützung der Geschäftsprozesse sowie eine stärkere Integration bestehender E-Business-, CRM- und SCM-Initiativen. Diesen Erwartungen steht jedoch entgegen, dass die Anforderungsanalyse für Web Service Kompositionen sehr komplex ist. Dafür gibt es eine Reihe von Gründen: Erstens arbeiten in entsprechenden Projekten typischerweise Software-Ingenieure mit unterschiedlichen Fähigkeiten, Erfahrungen und fachlichem Hintergrund zusammen, was eine eindeutige und konsistente Spezifikation fachlicher Anforderungen erschwert. Zweitens wurden die zu komponierenden Web Services womöglich nicht für Komposition entwickelt, weswegen unklar sein kann, ob diese die geforderten fachlichen Anforderungen überhaupt erfüllen können. Drittens kann – wie bei verteilten (asynchronen) Systemen üblich – aufgrund der Vielzahl an möglichen Abläufen oftmals nur mit sehr hohem Aufwand zur Entwicklungszeit geprüft werden, ob Web Service Kompositionen die fachlichen Anforderungen tatsächlich einhalten. Falls nicht, können Verletzungen von Service Level Agreements (SLAs) zu Vertragsstrafen führen und die Reputation der beteiligten Unternehmen negativ beeinflussen.

Mit der Verifikation (Floyd 1967; Hoare 1969) existiert in der Informatik eine Möglichkeit, das Einhalten fachlicher Anforderungen für einzelne Programme und verteilte Systeme zumindest eingeschränkt formal zu beweisen. Das Einhalten fachlicher Anforderungen wird als Korrektheit bezeichnet. Des Weiteren gewinnt die Verifikation von Web Service Kompositionen an Bedeutung (Van Breugel und Koshkina 2006). Aktuelle auch in der Wirtschaftsinformatik gebräuchliche Spezifikationssprachen, z. B. WS-BPEL (Alves et al. 2007), und serviceorientierte Modellierungsansätze, z. B. Service-oriented Modeling and Architecture (Arjansani 2004; Zimmermann et al. 2004), Service-oriented Modeling Framework (Bell 2008) oder Service-oriented Design and Development (Papazoglou und van den Heuvel 2006), tragen dem jedoch kaum Rechnung. Deshalb widmet sich Kapitel II diesem Thema.

Um Fehlinterpretationen vorzubeugen, sei eine kurze Diskussion des Verifikationsbegriffs erlaubt: In der Informatik versteht man unter Verifikation den formalen Beweis, dass die Implementierung eines Programms und die Spezifikation der geforderten fachlichen Anforderungen widerspruchsfrei sind (Balzert 1998, S. 445-472). Dies erfolgt i. d. R. durch Anwendung eines konkreten Verifikationsverfahrens. In der Wissenschaftstheorie versteht man unter Verifikation allgemein den Nachweis, dass eine Hypothese richtig ist (Eberhard 1999, S. 42). Beide Begriffsverständnisse können analog verwendet werden. Der zu prüfenden Hypothese entsprechen die geforderten fachlichen Anforderungen, dem Nachweis der Richtigkeit entspricht die Anwendung des Verifikationsverfahrens. Überdies beruhen manche wissenschaftstheoretische Positionen,

z. B. der Logische Empirismus, auf der Verifikation von Hypothesen bzw. Theorien als Methode des Erkenntnisfortschritts. Dies steht im Gegensatz zur Position des Kritischen Rationalismus nach Popper, der „eine dominierende Stellung im gegenwärtigen Wissenschaftsbetrieb“ (Eberhard 1999, S. 36) einnimmt. Erkenntnisfortschritt beruht hier auf Falsifikation und Korrektur, also auf „wiederholte[m] Verwerfen wissenschaftlicher Theorien und ihre[m] Ersatz durch bessere oder befriedigendere Theorien“ (Popper 1994, S. 312). In dieser Arbeit wird Verifikation ausschließlich im Sinn der Informatik als Hilfsmittel zur Prüfung von Programmen verwendet. Nicht jedoch liegt den Beiträgen auf einer wissenschaftstheoretischen Ebene die Verifikation als Methode des Erkenntnisfortschritts zugrunde.

Kapitel II: Anforderungsanalyse für verteilte Systeme – am Beispiel Web Service-basierter Systeme (Beitrag: „Verification of Web Service compositions: An Operationalization of Correctness and a Framework for Service-oriented Modeling Techniques“)

Damit serviceorientierte Modellierungsansätze bez. Verifikation erweitert werden können, ist ein grundlegendes Verständnis des Korrektheitsbegriffs für Web Service Kompositionen erforderlich. Zu diesem Zweck wird eine auf der allgemeinen Systemtheorie basierende Konkretisierung des Korrektheitsbegriffs vorgeschlagen. Auf dieser Basis wird ein Anforderungskatalog für serviceorientierte Modellierungsansätze zusammengestellt. Der in diesem Beitrag vorgeschlagene Katalog umfasst (harte) Anforderungen an die Spezifikation von Web Service Kompositionen und fachlichen Anforderungen sowie (weiche) Anforderungen an den Modellierungsprozess und dessen Systemunterstützung. Dabei stehen u. a. folgende Forschungsfragen im Mittelpunkt:

1. Wie kann der generische Korrektheitsbegriff der formalen Verifikation für Web Service Kompositionen konkretisiert werden?

2. Wie müssen serviceorientierte Modellierungsansätze gestaltet werden, damit Web Service Kompositionen intuitiv modelliert und Korrektheit mittels Verifikation formal geprüft werden kann?

2.2 Anforderungsanalyse für Planungs- und Kontrollsysteme

Aufgrund der Komplexität inner- und außerbetrieblicher Strukturen und Prozesse ist es Entscheidungsträgern im Allgemeinen nicht möglich, sämtliche Handlungs- und Problemfelder kontinuierlich zu überwachen (Gladen 2005; Gluchowski et al. 2008). Ein nach wie vor ungelöstes Problem im Rahmen der Anforderungsanalyse für Planungs- und Kontrollsysteme ist die Auswahl von Handlungsfeldern und steuerungsrelevanten Kennzahlen (Eccles 1991; Watson und Frolick 1993; Evans 2004). Zwar helfen klassische Ansätze der Informationsbedarfsanalyse, z. B. der Ansatz der kritischen Erfolgsfaktoren (Rockart 1979), oder vorgefertigte Bausteine („Templates“ / „Business Content“), z. B. in SAP® BI® (Mertens und Meier 2008), den Informationsbedarf von Entscheidungsträgern zu strukturieren und thematisch passende Kennzahlen vorauszuwählen. Unklar bleibt, wie viele und welche dieser Kennzahlen letztlich in Berichte aufgenommen werden sollen. Bedenkt man, dass durchschnittliche Berichte in etwa 15.000 Datenpunkte umfassen (Axson 2007), wird deutlich, dass einige Kennzahlen mehr oder weniger die Berichtskomplexität durchaus beeinflussen. In der betrieblichen Praxis werden derartige Auswahlentscheidungen oftmals auf der Grundlage von „Bauchgefühl“ getroffen und kaum methodisch unterstützt. Der Nutzen ausgewählter Kennzahlen bleibt somit nebulös und der Auswahlprozess nur bedingt intersubjektiv nachvollziehbar. Deshalb widmet sich Kapitel III diesem Thema:

Kapitel III: Anforderungsanalyse für Planungs- und Kontrollsysteme

> Zur Fundierung des Auswahlprozesses gilt es in einem ersten Schritt, den Nutzen von Kennzahlen zu quantifizieren. In einem zweiten Schritt können Kennzahlen über einen Trade-Off von informationellen und ökonomischen Zielen ausgewählt werden. Zu den informationellen Zielen gehören z. B. eine möglichst umfassende Informationsversorgung von Entscheidungsträgern und – konfliktär dazu – eine möglichst geringe Berichtskomplexität. Letzteres resultiert z. B. aus der beschränkten Informationsverarbeitungskomplexität von Entscheidungsträgern (Davis 1982; Browne und Ramesh 2002) sowie konzeptionellen Limitationen von Berichtswerkzeugen wie z. B. Management Cockpits und Dashboards (Sisfontes-Monge 2007). Zu den ökonomischen Zielen gehören z. B. möglichst geringe Auszahlungen für Konfiguration und Wartung von Berichten. Im ersten Beitrag werden ein Bewertungsschema für den

Nutzen von Kennzahlen und ein basaler Auswahlalgorithmus vorgeschlagen. Der Schwerpunkt liegt dabei auf sog. Kennzahlennetzen, einer Unterklasse von Kennzahlensystemen, in der Zusammenhänge zwischen Kennzahlen nicht hierarchisch-sachlich bzw. mathematisch-logisch – z. B. in Form von mathematischen Funktionen – ausgedrückt werden, sondern auf sog. empirische bzw. statistische Zusammenhänge – z. B. in Form von Kontingenz- bzw. Korrelationskoeffizienten – als Hilfsgrößen zurückgegriffen wird (Gladen 2005; Küpper 2005). Im zweiten Beitrag werden die o. g. informationellen und ökonomischen Ziele in ein quantitatives Optimierungsmodell integriert, um den basalen Auswahlalgorithmus weiterzuentwickeln. Es stehen u. a. folgende Forschungsfragen im Mittelpunkt:

1. Welche Kennzahlen sollen aus einem bestehenden Kennzahlennetz ausgewählt werden, um Entscheidungsträger über einen abgegrenzten betrieblichen Sachverhalt zweckmäßig zu informieren?

2. Wie viele und welche Kennzahlen sollen aus einer vorausgewählten Menge an thematisch passenden Kennzahlen ausgewählt werden, um Entscheidungsträger in Bezug auf informationelle und ökonomische Ziele optimal mit Informationen zu versorgen?

2.3 Anforderungsanalyse für operative Systeme – am Beispiel von CRM-Systemen

Trotz einer Vielzahl an Studien im Bereich CRM und CRM-Erfolgsfaktoren scheitern CRM-Projekte – und damit die Einführung von CRM-Systemen – angeblich in einer Größenordnung von bis zu 75 % (Langerak und Verhoef 2003; Reinartz et al. 2004) – was natürlich kritisch zu hinterfragen ist. CRM ist dabei ein strategischer und IT-gestützter Ansatz, um den Unternehmenswert über profitable und i. d. R. langfristige Kundenbeziehungen zu steigern (Payne und Frow 2005; Goodhue et al. 2002). Ein Grund für das häufige Scheitern mag sein, dass der Projekt- und Technologieperspektive im Vergleich zur Organisations- bzw. Prozessperspektive deutlich mehr Aufmerksamkeit zukommt. Damit ist eine Reihe von Nachteilen verbunden: Erstens vernachlässigen Studien, die CRM auf eine Technologieperspektive reduzieren, dass dies ein Hauptgrund für das Scheitern von CRM-Projekten ist (Dibb 2001; Kim und Mukhopadhyay 2006). Zweitens steht dies einer ganzheitlichen Umsetzung von CRM entgegen, die z. B. von

Payne und Frow (2005) gefordert wird. Drittens bezieht sich ein Großteil der identifizierten Erfolgsfaktoren auf CRM-Entwicklung/-Einführung, also die CRM-Projektphase. Erfolgsfaktoren für den CRM-Betrieb werden kaum untersucht. Dies verwundert, bedenkt man, dass die Betriebsdauer die Entwicklungsdauer bzw. die Betriebskosten die Entwicklungskosten um ein Vielfaches übersteigen und dass Erfolgsfaktoren für den CRM-Betrieb bereits während der Anforderungsanalyse identifiziert und bei der Gestaltung des CRM-Systems bzw. des organisatorischen und prozessualen Nutzungsumfelds berücksichtigt werden sollten. Viertens sind die identifizierten Erfolgsfaktoren eher abstrakt, was ihren Nutzen für die betriebliche Praxis schmälert. Einige Beispiele sind „Managementunterstützung“, „Entwurf für Flexibilität“, „Bewusstsein im Vorstand über das strategische Potenzial von IT“. Es lässt sich festhalten: Es gibt einen Überfluss an eher abstrakten Erfolgsfaktoren, die sich auf Entwicklung bzw. Einführung von CRM beziehen. Zudem gibt es Forschungsbedarf hinsichtlich konkreter Erfolgsfaktoren für den CRM-Betrieb – im Folgenden als operative CRM-Erfolgsfaktoren bezeichnet. Da diese einen wertvollen Beitrag im Rahmen der Anforderungsanalyse leisten, widmet sich Kapitel IV diesem Thema:

Kapitel IV: Anforderungsanalyse für operative Systeme – am Beispiel von CRM-Systemen (Beitrag: „A multi-perspective analysis of operational critical success factors for customer relationship management – A descriptive case study“)

> Im vorgestellten Beitrag stehen operative Erfolgsfaktoren von Vertriebsbereichen im Vordergrund. Diese sind neben Marketing- und Servicebereichen von zentraler Bedeutung für CRM. Der Fokus wird in dreierlei Hinsicht geschärft: Erstens werden Vertriebsbereiche betrachtet, die Geschäftskunden über flächendeckenden Direktvertrieb bedienen. Dies ist untersuchenswert, da solche Vertriebsbereiche typischerweise eine hohe Mitarbeiterzahl, ein komplexes Zusammenspiel zwischen Außendienst, Innendienst und anderen Abteilungen, ein differenziertes Leistungsportfolio, eine mehrstufige Managementhierarchie sowie komplexe fachliche Anforderungen an CRM-Systeme aufweisen. Zweitens werden Erfolgsfaktoren aus dem Blickwinkel von Vertriebsbeauftragen – im Sinne von Außendienstmitarbeitern – untersucht, da diese in eben skizzierten Vertriebsbereichen am meisten Kundenkontakt haben und vorhandene CRM-Systeme am intensivsten nutzen dürften. Drittens werden drei Perspektiven betrachtet: organisatorische Rahmenbedingungen, CRM-Prozesse und

Informationsbedarf. Die Untersuchung basiert auf der Fallstudienmethode. Dies schien angemessen, da ein unstrukturiertes Phänomen – nämlich operative CRM-Erfolgsfaktoren – in seinem realen Kontext untersucht werden sollte (Yin 2009). Die Fallstudie wurde im für Deutschland verantwortlichen Vertriebsbereich eines Unternehmens der Elektronikbranche durchgeführt, da es sich einerseits um einen typischen Fall zu handeln schien und andererseits im Rahmen einer Projektpartnerschaft Zugang zu Daten und Interviewpartnern bestand. Es standen u. a. folgende Forschungsfragen im Mittelpunkt:

1. Welches sind die operativen CRM-Erfolgsfaktoren hinsichtlich der Perspektiven organisatorische Rahmenbedingungen, CRM-Prozess und Informationsbedarf für Vertriebsbeauftragte aus Vertriebsbereichen, die vorwiegend Geschäftskunden über flächendeckenden Direktvertrieb bedienen?

2. Welches sind die Unterschiede und Gemeinsamkeiten bez. operativer CRM-Erfolgsfaktoren im Produkt- und Lösungsvertrieb?

Abb. I-4 zeigt die untersuchten Anwendungssystemklassen und deren Zuordnung zu den Kapiteln der Dissertationsschrift.

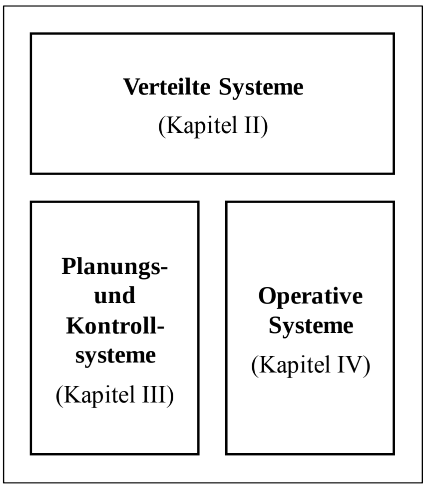

Abb. I-4 Untersuchte Anwendungssystemklassen und Zuordnung zu Kapiteln

Nach Einleitung, Zielsetzung und fachlicher Einordnung folgen in den Kapiteln II, III und IV die einzelnen Beiträge. Im Anschluss werden in Kapitel V die zentralen Ergebnisse zusammengefasst und Ansatzpunkte für künftigen Forschungsbedarf aufgezeigt.

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II Anforderungsanalyse für verteilte Systeme – am Beispiel Web Service-basierter Systeme (Beitrag: „Verification of Web Service compositions: An Operationalization of Correctness and a Framework for Service-oriented Modeling Techniques“)

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Erscheint in:	Business & Information Systems Engineering 1 (6) 2009

Abstract:

Web service compositions coordinate Web services of different enterprises. They are expected to constitute the foundation of service-oriented architectures, to improve business processes as well as to foster intra- and inter-organizational integration. Especially in inter-organizational contexts, quality of service referring to non-functional requirements and conformance to functional requirements are becoming vital properties. With Web service compositions being asynchronous and distributed systems, the latter property – which is also called correctness – can be shown best by verification. This paper examines from a system-theoretic perspective how correctness can be operationalized for Web service compositions. It also proposes a requirements framework for service-oriented modeling techniques so that correctness can be shown by verification and Web service compositions can be modeled intuitively. In order to show the framework's principle applicability, an example approach is analyzed with respect to the corresponding requirements.

1 Motivation and object of research

Web services and Web service compositions (WS compositions) are currently considered to be the most widespread possibility for implementing service-oriented architectures (Erl 2004; Newcomer and Lomow 2005). A (basic) Web service is a software system that exposes its functionality by means of a machine-processable interface consisting of several operations. It enables (asynchronous) message-based machine-to-machine interaction over a network (Booth et al. 2004). Web services are offered by internal IT departments or by external service providers. A WS composition is a Web service that realizes complex functionality by coordinating multiple (component) Web services in transactions (Alonso et al. 2004, p. 141). Analogous to (basic) Web services, WS compositions expose their functionality via interfaces. In this paper, WS compositions refer to the orchestration of Web services, not to their choreography (Dostal et al. 2005, p. 226).

According to a survey of the Yankee Group, WS compositions raise high expectations (Kallus 2004). Among other things, they are expected to improve business processes and to foster the integration of existing e-business, CRM, SCM, and ERP initiatives. Already in 2004, more than 50 % of the US companies relied on Web services whereof 60 % estimated their impact on business-to-business integration (very) high. However, designing and running WS compositions is error-prone. Involved teams of software engineers and modelers usually stem from multiple companies and have different skills, experiences, or functional backgrounds. Web services are usually managed by different companies and may not have been developed for composition. Analogous to other distributed systems based on asynchronous communication, it is difficult to anticipate how WS compositions behave during execution and whether they conform to the functional requirements identified during requirements engineering. Errors, however, may violate service level agreements. This may cause losses or penalties and have negative impact on the reputation of the companies involved. Therefore, it is an important task to make sure that WS compositions conform to their functional requirements.

A possibility of reliably showing conformance to functional requirements is verification. In this context, conformance to functional requirements is also called correctness. The idea of verification dates back to Floyd (1967) and Hoare (1969). In contrast to testing, for instance, where correctness can only be shown with respect to selected test data, verification aims at exhaustively proving correctness for all behavioral facets and inputs of a given program. During verification, the program is analyzed automatically. This requires the semantics of each program statement to be defined unambiguously. A program is said to be correct if its implementation (i. e. its program code or a corresponding formal model) is consistent with a corresponding specification of behavioral claims (i. e. functional requirements on the program's behavior) (Balzert 1998, pp. 445-472).

Despite the need for correctness, research focuses on non-functional requirements such as availability, scalability, capacity, etc. (Lee et al. 2003), which are already known from network research. Current approaches to (Web) service-oriented modeling do not (or hardly) cope with correctness and verification. This includes specification languages like the de facto standard WS-BPEL (Alves et al. 2007) – despite some attempts (e. g. Farahbod et al. 2005; Stahl 2005; Moser et al. 2007; Lohmann 2007) – and high-level approaches (Arjansani 2004; Bell 2008; Papazoglou and van den Heuvel 2006; Zimmermann et al. 2004). Current approaches to the verification of Web services (WS verification) require formal models, e. g. in terms of finite state automata or Petri nets, which are not necessarily intuitive for conceptual modelers. Such approaches also postulate a variety of formal claims on WS compositions so that it is not clear what correctness actually means.

Against this background, we address the following research questions: *How does correctness have to be operationalized so that it fits the peculiarities of WS compositions? How do (Web) service-oriented modeling techniques have to be shaped so that correctness can be shown by verification and WS compositions be modeled intuitively?*

This paper relies on a design-oriented, deductive, and argumentative research approach (Hevner et al. 2004; Wilde and Hess 2007). In section 2, we identify the research gap by compiling current approaches to WS verification and service-oriented modeling. Section 3 proposes a definition of correctness and a requirements framework as artifacts. Section

4 aims at showing the framework's basic applicability in the sense of a basic evaluation. Section 5 briefly summarizes the findings and points out further research.

2 State of the art

As for WS verification, the most frequently applied verification method is model checking (Clarke et al. 2001; Schneider 2004). This is because model checking is particularly suitable for verifying distributed systems of multiple components that interact via message exchange. WS compositions are such distributed systems. In contrast to other verification methods, model checking does not directly work on implementations in the sense of program code, but on formal models that focus on relevant details such as exchanged messages and their content. A variety of model checking-based approaches has been proposed for WS verification (Van Breugel and Koshkina 2006). WS compositions are usually modeled by means of finite state automata (e. g. Fu et al. 2004a), Petri nets (e. g. Martens 2005; Rozinat and van der Aalst 2008; Schlingloff et al. 2005), abstract state machines (e. g. Fahland and Reisig 2005; Farahbod et al. 2004), or process algebras (e. g. Ferrara 2004). Some approaches are also capable of translating XML-based models of WS compositions (see below). Behavioral claims are commonly formalized by means of temporal logics. This is because it enables to reason about the content and temporal interdependencies of exchanged messages without introducing time explicitly (Clarke et al. 2001, p. 4).

In the following, we do not discuss the approaches in their entirety, but focus on how they deal with correctness and behavioral claims. Most approaches enable to specify behavioral claims that refer to concrete use cases. This is done by means of temporal logics as just mentioned. Some approaches additionally postulate claims that do not refer to concrete use cases. This is mostly done with respect to the formalism employed. The following list shows selected claims of the latter category:

- *Usability* requires a WS composition to terminate properly (Martens 2005, p. 26; Schlingloff et al. 2005, p. 11; Kopp et al. 2006).

- *Syntactic compatibility* requires that two Web services can be composed with respect to their interfaces, i. e. names of messages (Martens 2005, p. 23).
- *Semantic compatibility* requires that the composition of two Web services fulfills the usability claim (Martens 2005, p. 26).
- *Fitness* indicates up to which percentage the behavior of a WS composition conforms to its implementation (Rozinat and van der Aalst 2008, p. 67).
- *Appropriateness* indicates whether the implementation of a WS composition adequately characterizes the observed behavior (Rozinat and van der Aalst 2008, p. 67).

Beyond, there are also claims on the equivalence of WS compositions (Martens 2005, p. 27; Kopp et al. 2006) or on whether the communication pattern of multiple Web services could be simulated by synchronous message exchange (Fu et al. 2004a, p. 627). As these claims refer to correctness at best indirectly, they are omitted for the further discussion.

The following is noteworthy: No approach states how the claims it proposes refer to the overall concept of correctness. It remains unclear whether any subset of these claims would be sufficient, whether (or how) claims of several approaches cohere, and whether they fit the peculiarities of WS compositions. Some claims depend on the underlying formalism (e. g. usability was defined for Petri nets), others are too generic (e. g. syntactic compatibility refers to the names of messages, semantic compatibility is limited to termination). It is not discussed whether these claims can be structured. Concluding, there is a research gap with respect to how correctness can be operationalized so that it fits the peculiarities of WS compositions.

When presenting an operationalization in the next section, we adopt several existing ideas in order to provide an incremental contribution. We adopt the idea that there are claims that refer to concrete use cases and others that do not. The latter category, for instance, would include usability as termination-related requirement. We extend syntactic compatibility from message names to operations and parameters. This is appropriate because correctness rather depends on the content of exchanged messages. We also extend semantic compatibility to possible (input and output) values and value ranges of parameters (see below) as well as to behavioral claims referring to concrete use cases. This enables to reason about sequences of exchanged messages and concrete behavior. We omit fitness as we consider correctness as a dichotomous property, that is, a WS composition is either correct or not. We also omit appropriateness as is takes on a contrary perspective by indicating whether an implementation characterizes observed behavior well. As additional contribution, we structure correctness by means of a system-theoretic perspective. This is suitable as each WS composition can be characterized by structure and behavior. In general, claims on a WS composition's structure (e. g. syntactic compatibility) do not require verification as they deal with static aspects. Behavioral claims, in contrast, require verification as they address dynamic aspects. This distinction enables to assess correctness in a less complex manner.

As for (Web) service-oriented modeling, there are technical XML-based specification languages and comprehensive high-level approaches. With respect to the former category, service interfaces, operations, and parameters are formalized by means of the Web Service Description Language (WSDL) (Christensen et al. 2001). Messages exchanged to invoke other services' operations are commonly specified in terms of SOAP (Mitra 2003). WS compositions are specified by means of the Web Services Business Process Execution Language (WS-BPEL) (Alves et al. 2007), the Web Services Choreography Description Language (WSCDL) (Kavantzas et al. 2005), the Business Process Modeling Language (BPML) (Dubray 2008), or the Web Service Choreography Interface (WSCI) (Arkin et al. 2002) (for an overview see e. g. Peltz 2003). In the context of the Semantic Web, there are specification languages for modeling the semantics of operations and parameters, e. g. possible (input and output) values and value ranges. They include the Resource Description Framework (RDF) (Klyne and Carroll 2004) and the Web Ontology Language for Web services (OWL-S) (Martin et al. 2004) (for an introduction see e. g. Herman 2003). As for high-level approaches, three examples are presented here. The service-oriented modeling and architecture approach proposes a framework for service identification, specification, and realization including role models for service providers and consumers (Arjansani 2004; Zimmermann et al. 2004). The service-oriented modeling framework is a high-level map depicting the various components that contribute to a service-oriented modeling approach, namely conceptual, analysis, and logical environment (Bell 2008, p. 23). The service-oriented design and development methodology covers the entire service development lifecycle from service analysis and design to service execution and monitoring (Papazoglou and van den Heuvel 2006). It illustrates each phase in detail and proposes general design principles for SOA. It also acknowledges the importance of correctness (Papazoglou and van den Heuvel 2006, p. 435).

The high-level approaches do not elaborate on how service-oriented modeling techniques should be shaped so that correctness can be shown by verification while WS compositions can be modeled intuitively. Moreover, the specification languages from above, e. g. WS-BPEL, are currently not or hardly amenable to verification. Thus, there also is a research gap. As the high-level approaches do not provide any concrete hint on how to integrate verification, it is not possible to make an incremental contribution. Therefore, we examined general requirements of verification and conceptual modeling with respect to WS compositions and tried to integrate them into a requirements framework. Moreover, we used the specification languages in order to define the structural requirements of correctness independent of the formalisms for WS verification.

In the following, we operationalize correctness based on the deliberations from above. We then elaborate on the requirements framework.

3 Artifacts

3.1 A definition of correctness for web service compositions

We analyze correctness from a system-theoretic perspective. This seems appropriate because WS compositions can be interpreted as general systems characterized by structure and behavior (Ferstl and Sinz 2006, p. 12). The structure of a WS composition encompasses the WS composition itself, the component Web services, and the message types they may exchange. The latter are given by the WS composition’s invocation statements and by the operations of the component Web services' interfaces. The behavior of a WS composition represents the actual interaction among the WS composition and its component Web services. This includes the set of all message sequences (i. e. sequences of operation invocations). In accordance with this point of view, we propose that correctness splits into structural and behavioral correctness.

3.1.1 Structural correctness

WS compositions virtually have two interfaces: a "provides interface" and a "requires interface" (Sommerville 2004, p. 444). The former comprises the operations by which a WS composition provides its functionality to other Web services. The latter includes the operations a WS composition requires in order to implement its functionality. Component Web services only have a "provides interface" because they are only known from an external perspective.

Structural correctness requires that for each operation of the WS composition's "requires" interface there is at least one identically named operation in a component Web services "provides" interface that matches with respect to number, sequence, and types of parameters. One possibility to check this is to compare the component Web services' WSDL interfaces and the invocation statements of the WS composition's WS-BPEL specification. If mandatory and optional parameters are distinguished, only mandatory parameters need to match. If the WS composition and the component Web services are semantically annotated, operations also have to match with respect to possible (input and output) parameter values or value ranges, for instance. It is not necessary that each operation of the component Web services' "provides" interfaces has a matching operation in the WS composition's "requires" interface. This is because component Web services may of course provide more functionality than required.

In many cases, component Web services are discovered and selected at run time. WS compositions may be executed although not all required operations are available. In contrast, state-of-the-art verification techniques (e. g. Fu et al. 2004a; Martens 2005) require all operations to be available and models of WS compositions to be completely specified.

Otherwise, they cannot be processed by verification tools and correctness cannot be analyzed. That is, if a component Web service is not available, one can neither reason about its own behavior nor its implications on the WS composition's global behavior. To overcome this discrepancy, verification could take place at design time or be shifted to the point in time during execution where all component services have been selected. As WS compositions and/or behavioral claims may have to be changed after verification, one would have to accept human interaction in the latter case.

3.1.2 Behavioral correctness

Behavioral correctness requires sequences of messages to conform to a set of behavioral claims. As messages can only be exchanged if required and provided operations match and all required operations are provided, structural correctness is a prerequisite of behavioral correctness. In literature, behavioral claims split into safety claims and liveness claims (Schneider 2004, p. 14). Safety claims are claims that must not be violated, whereas liveness claims must always hold (Holzmann 2003, p. 74). This distinction does not sufficiently characterize behavioral correctness of WS compositions. What is missing is a complementary distinction between application-independent and application-dependent claims (see section 2). This allows to separate generic claims for many use cases from particular claims for only a couple of use cases, which fosters reusability.

- *Application-independent claims*: Claims that cover generic issues resulting from the distributed and asynchronous nature of WS compositions are called application-independent claims. They occur in many use cases and may be captured in a rather standardized manner. There are application-independent safety and liveness claims. Typical claims of the former category are mutual exclusion and deadlock freedom. Mutual exclusion guarantees the integrity of business data (e. g. available stock, account balances) by ensuring that shared variables or other critical sections are never accessed by more than one component Web services at the same time. Deadlock freedom is necessary for the termination of WS compositions. Otherwise, it would be possible that two or more component Web services wait for one another. A typical claim of the latter category is starvation freedom, which is closely related to termination and deadlock freedom. A Web service is said to starve if it has requested a resource (e. g. a document or a database entry) that is currently being held by another Web service not willing to release it. Starvation freedom guarantees by means of some fairness policy that each request for a resource is eventually satisfied.

- *Application-dependent claims*: Claims that vary with a WS composition's use case are called application-dependent claims. They are much more difficult to discover because they are only valid for some or only one use case. For this reason, it is impossible to enumerate them exhaustively. Some claims occur more than once and can be structured into catalogs of domain-specific claims. For example, there might be a catalog for commercial applications. A corresponding safety claim may be that customers do not have to pay for goods they have not ordered. A corresponding liveness claim may be that each customer who places an order will eventually receive an invoice. The advantage of this catalog is that it applies to all use cases where customers order goods or services. Nevertheless, some application-specific claims apply to just one scenario so that they need to be assessed individually.

Tab. II-1 summarizes the types and examples of behavioral claims.

Tab. II-1 Types and examples of behavioral claims

	Safety claims	**Liveness claims**
Application-independent claims	Mutual exclusion Deadlock freedom	Starvation freedom
Application-dependent Claims	"A customer never pays for goods he has not ordered."	"A customer eventually receives an invoice."

3.2 A requirements framework for service-oriented modeling techniques

Now that correctness has been examined, it is assessed what requirements (Web) service-oriented modeling techniques have to meet so that correctness can be shown by verification and WS compositions can be modeled intuitively. Therefore, we propose a requirements framework considering two complementary perspectives: formal foundations and modeling support.

- *Formal foundations*: Verification requires models and specifications of WS compositions to conform to formal languages and their semantics to be defined unambiguously (Balzert 1998, p. 467). This enables to "compute" all behavioral facets of WS compositions and to check which of them violate the specification. Only formally well-founded models and specifications are amenable to verification tools.

- *Modeling support*: Whereas requirements on formal foundations are compulsory with respect to technical amenability to verification, modeling techniques should also consider the modelers' capabilities and limitations of information processing. This is important for several reasons: First, in the context of business and information systems engineering as an inter-discipline, models aim at reducing complexity and at fostering the communication among modelers and model users (Ferstl and Sinz 2006, p. 123). Second, in the context of WS compositions, modelers from different enterprises with different skills, experiences, and functional backgrounds cooperate. Third, verification tools operate on a technical level so that their output is difficult to understand for conceptual modelers. Fourth, modeling behavioral claims is error-prone so that modeling tools should support modelers as good as possible.

Tab. II-2 shows the requirements framework. In the following, each requirement will be presented. The *formalization of models* of WS compositions requires formal syntax and formal semantics.

- *Formal syntax*: The syntax of a modeling language encompasses elements as well as rules that prescribe how to combine elements. To cover the behavioral facets of WS compositions, elements for manipulating the conversational state (e. g. assignment of variables), message exchange (e. g. synchronous and asynchronous send / receive), and control flow (e. g. conditions, iterations, concurrency) are necessary. Syntax is formal if it is specified in terms of non-prosaic meta models or mathematic models.

- *Formal semantics*: Semantics builds upon syntax and deals with the meaning of elements. The semantics of a WS composition represents its behavior resulting from the interplay of its elements. It should deal with issues of distributed and asynchronous systems such as concurrency and non-determinism. Most modeling languages in the field of business and information systems engineering provide formal syntax, only few provide formal semantics.

The *formalization of specifications* requires a formal language for behavioral claims, e. g. temporal logics as mentioned above. With models and specifications serving as input for the same verification tool, it is important that this formalism complies with the modeling language employed for describing the semantics.

Tab. II-2 Requirements framework for service-oriented modeling techniques

Formal Foundations	Modeling Support
Formalization of models • Formal syntax • Formal semantics	**Process model**
Formalization of specifications	**Tool support** • Reduction of complexity • Visualization of behavior • Integrated modeling of WS compositions and specifications • Constructive feedback

Modeling support requires a *process model* that guides the modeler through the process of modeling and verifying WS compositions. In particular, the process model should include the modeling of specifications and their harmonization with models of WS compositions. It should contain a “loop” from verification back to the modeling of models and specifications because models and specifications may need to be modified several times after verification.

Beyond, modeling techniques are requested to provide *modeling and verification tools* that fulfill the following requirements:

- *Reduction of complexity*: As models of WS compositions typically refer to multiple business partners and represent complex behavior, they easily overstrain the modelers' capacity of information processing. Modeling tools should provide graphical means for reducing complexity. Especially the interfaces of WS compositions enable modelers to switch between internal and external perspectives and to focus on a particular section of a model.

- *Visualization of behavior*: Behavior is often visualized in a static manner. That is, carriers of behavior (e. g. activities, functions, tasks) are identified and related according to their temporal or behavioral logic. This does not correspond to human imagination. Modeling tools should be able to simulate the execution of WS compositions. Modelers should be able to chose among different execution possibilities and get an intuitive awareness of possible errors and bottlenecks.

- *Integrated modeling of WS compositions and specifications*: Models and specifications of WS compositions cohere closely as they represent actual and expected behavior respectively. Additionally, the formalization of behavioral claims is error-prone and needs to be harmonized with the peculiarities of concrete representations of WS compositions. Modeling tools should enable the integrated modeling of WS compositions and specifications.

- *Constructive feedback*: If behavioral claims are violated, the reasons may not be immediately obvious. This is for two reasons: First, models and/or specifications may contain errors. Second, errors are difficult to reconstruct in a distributed environment. Verification tools should provide modelers with constructive feedback on where and under what circumstances behavioral claims are violated. As this feedback typically is highly technical, modeling tools should furthermore be able to represent this feedback in a way understandable for modelers.

We hypothesize that modeling techniques that meet these requirements enable to show correctness by verification and to model WS compositions intuitively.

4 Basic evaluation of the requirements framework

In order to provide a basic evaluation, we will now analyze whether the requirements framework is principally applicable. In the following, we present a selected approach, analyze it with respect to the requirements, and assess whether this leads to reasonable findings. The approach is that of Fu et al. (2004a; 2004b; 2006; 2005). It has been chosen because it is an elaborate framework for analyzing, designing, and verifying WS compositions (Fu et al. 2004a, p. 622), has already been applied to WS-BPEL processes, relies on the state-of-the-art model checker SPIN (Holzmann 2003), and has been published in several international journals and conferences. In order to be more illustrative, we refer to a widely known example from the previous WS-BPEL version known as BPEL4WS version 1.1 (Andrews et al. 2003).

The example is as follows: A bank intends to acquire more business customers (BIZ). A survey disclosed that business customers complain about administrative overhead when applying for short-term loans of moderate value. The board has decided to improve the process: Future loan applications will be classified by amount and risk. The latter will be assessed by an external association of experts (ASS). Only critical applications, i. e. those with an amount higher than or equal to 10,000 Euros or with high risk, will be examined by in-house loan approvers (APP). Business customers should apply via the Internet. As both the external experts and the internal loan approvers offer their functionality by means of Web services, the additional functionality will be implemented by means of a WS composition. Thereby, the bank unites its loan approval authority and external risk assessment competences in a single loan service composition (LNS). The bank is interested in that the loan service composition conforms to the following two application-dependent functional requirements (behavioral claims): First, loan applications with a high amount must be investigated in detail because, according to Basel II, each loan has to be guaranteed with a risk-dependent amount of equity. Second, in order to satisfy its customers' needs, each loan application of less than 10,000 Euros and low risk should be granted.

Technically speaking, the WS composition (LNS) coordinates the functionality of two Web services (APP and ASS), and is used by a third Web service (BIZ). Three message types are necessary: request messages (*req*) that contain the requested amount of money (*amount*), approval messages (*app*) that contain the bank's decision (*result*), and risk assessment messages (*ass*) that contain the risk classification (*risk*).

In the approach of Fu et al., WS compositions are modeled by means of guarded finite state automata (GFSA). Informally speaking, finite state automata consist of states and transitions. States store information about the past. Transitions convey automata from one state to another upon external stimuli, e. g. sent or received messages. In order to deal with the content of messages, send-transitions are annotated with guards. Analogous to production rules, each guard consists of a condition part and an action part. The former specifies the transition's precondition. The latter specifies the content of the message being sent. Guards are formalized by means of XPath (Clark and DeRose 1999). Receive-transitions are not guarded because the content of received messages cannot be controlled.

Fig. II-1 shows how the example can be modeled by means of GFSA. We use the standard notation for automata. States are modeled as circles, transitions as directed edges. Final states are modeled as two concentric circles, initial states as circles with edges that point to them from "nowhere". Each transition has two annotations. The first annotation indicates which message is currently being sent (!) to or received (?) from which automaton. We use indexes to distinguish several message instances of the same type (e. g. req_1, req_3). The second annotation (in squared brackets) specifies the guard. We use apostrophes to characterize that messages are forwarded ($req_3' = req_1$) or new values are assigned to variables (e. g. $app_1'.risk$ = "low"). For each WS composition and Web service, there is an automaton. Let us, for instance, consider the loan assessor's automaton (ASS). In its initial state, the automaton is waiting for a request message (req_3) forwarded by the loan service composition ($?req_3 \leftarrow$LNS). After that, the assessors' risk classification is returned to the loan service composition (LNS) via a risk assessment message (*ass*$_1$) (!*ass*$_1$→LNS). As the result can be “high” or “low”, the corresponding transition indicates both possibilities. As *ass*$_1$ can always be sent, the guard condition is true.

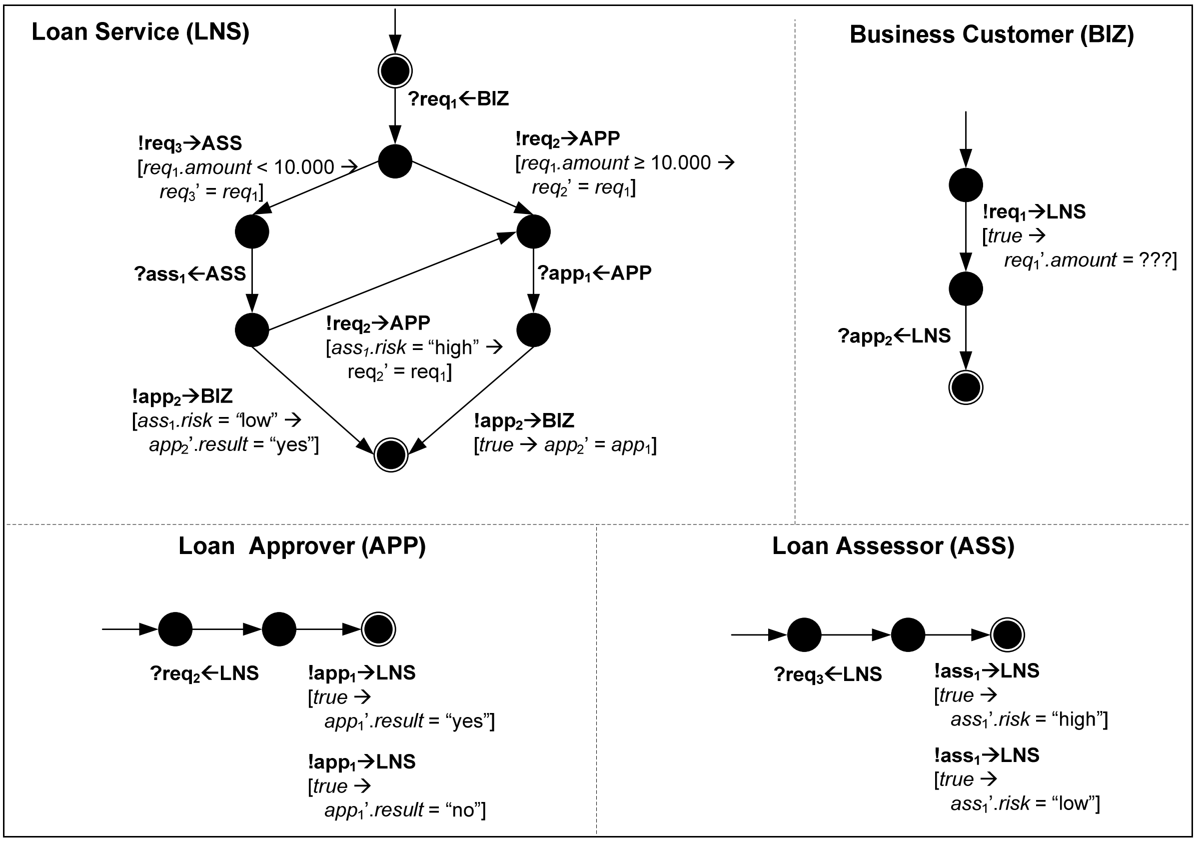

Fig. II-1 The example scenario modeled with guarded finite state automata (GFSA)

Behavioral claims are formalized by means of Linear Time Temporal Logic (LTL), which counts among temporal logics (see section 2). LTL extends propositional logic by temporal operators. These indicate how propositional expressions (e. g. specific variable assignments) cohere in time (Holzmann 2003, p. 135). Two exemplary temporal operators – which will be useful below – are *globally (G)* and *eventually (F)*. The former requires that the propositional expression to which it refers remains true throughout the run of the automata (i. e. the execution of the WS composition). The latter requires that the propositional expression to which it refers becomes true at least once during the run of the automata. As each LTL formula can be transformed into a GFSA (Vardi and Wolper 1986, p. 332), it is useful to use both approaches together.

Let us, for instance, formalize the second behavioral claim from above. It requires req_1 to contain an amount of less than 10,000 Euros ($req_1.amount < 10{,}000$), ass_1 to indicate “low” risk ($ass_1.risk =$ *“low”*), and app_2 to indicate acceptance ($app_2.result =$ *“yes”*). Temporally speaking, the claim must hold throughout the entire execution. Thus, it must be globally (*G*) true. The fact that req_1 and ass_1 lead to app_2 is modeled as implication (→). Although it is not known when exactly app_2 is returned, it must eventually (*F*) be returned. Together, these considerations result in the following LTL formula: $G(req_1.amount < 10{,}000 \wedge ass_1.risk = \text{“low”} \rightarrow F(app_2.result = \text{“yes”}))$. This formula can be translated into an automaton and serve – together with the automata from above – as input for the model checking tool SPIN, which analyzes whether the claims holds or not.

How does the approach of Fu et al. conform to the requirements framework from above? With respect to formal foundations, GFSA provide formal syntax and semantics that cover the behavioral facets of WS compositions. LTL enables to formalize both application-independent and application-independent behavioral claims. It also complies with GFSA. As for modeling support, the approach provides a verification-centered process model that is implemented by the proprietary tool WSAT (Web Service Analysis Tool) (Fu et al. 2004b). This tool, however, does not enable to model WS compositions and specifications, neither separately nor jointly. Both must be modeled by hand. Modelers have to cope with the complexity on their own. The employed model checking tool SPIN provides constructive feedback. This feedback, however, is presented in a technical way and only hardly suitable for conceptual modelers. Summing up, according to the requirements framework, the approach could be improved in the following ways: First, the tool should enable to model behavioral claims together with WS compositions (ideally in a graphical manner). Second, this tool should be integrated with the verification tool so that the feedback of the verification process can be integrated with the representation of WS compositions.

It may be stated that the analysis leads to reasonable results. Each requirement could be assessed. It could be pointed out how the approach of Fu et al. can be improved. This corroborates our hypothesis from above – at least basically and in the sense of principle applicability.

5 Summary and further research

We addressed the research gap with respect to how correctness can be operationalized for WS compositions and how (Web) service-oriented modeling techniques should be shaped so that correctness can be shown by verification and WS compositions can be modeled intuitively. We propose that correctness splits into structural and behavioral correctness. The former requires the interfaces of WS compositions and component Web services to match with respect to operations and parameters. The latter requires the behavior of WS compositions to conform to specifications of application-independent and application-dependent behavioral claims. The proposed requirements framework covers the perspectives “formal foundations” and “modeling support”. The first perspective requires formal syntax and semantics for models of WS compositions and a compatible formalism for behavioral claims. The second perspective requires a process model as well as modeling tools that reduce modeling complexity, visualize the behavior of WS compositions, integrate models of compositions and specifications, and integrate the feedback of verification tools. The requirements framework has been basically evaluated by analyzing an example approach.

The results will be subject to the following research:

1. The framework comprises requirements on a conceptual level. It has only been assessed for one example approach how it could be improved, i. e. refined or extended, in order to meet the requirements. This is where further research in the sense of a comprehensive survey would be useful.

2. The requirements framework focuses on formal foundations and modeling support. It does not provide an economic perspective on verification. Showing correctness leads to overhead. This is because specifications have to be created, models have to be veri-

fied, and specifications and/or models may have to be modified repeatedly. However, for many use cases it cannot be stated in advance whether the utility realized by preventing erroneous WS compositions justifies this overhead. This economic trade-off constitutes an interesting field of further research.

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III Anforderungsanalyse für Planungs- und Kontrollsysteme

In diesem Kapitel werden Planungs- und Kontrollsysteme hinsichtlich der Anforderungsanalyse näher untersucht. Dazu gehören z. B. Führungsinformationssysteme (FIS), Managementinformationssysteme (MIS), Entscheidungsunterstützungssysteme (ESS) und Business Intelligence-Systeme, die jedoch nicht immer trennscharf unterschieden werden. Planungs- und Kontrollsysteme versorgen Entscheidungsträger höherer Führungsebenen mit entscheidungsrelevanten Informationen und/oder unterstützen diese, indem sie z. B. auf der Basis bereits implementierter Entscheidungsmodelle Alternativen bewerten, Informationen vorauswählen oder strukturieren. Aufgrund der quasi ubiquitären Verfügbarkeit von Informationstechnologie steht Entscheidungsträgern eine kognitiv nicht mehr bewältigbare Fülle an inner- und außerbetrieblichen Informationen zur Verfügung. Gleichzeitig ist es ihnen aufgrund der damit einhergehenden Komplexität i. d. R. unmöglich, sämtliche Handlungs- bzw. Problemfelder permanent zu überwachen. Im Rahmen der Anforderungsanalyse für Planungs- und Kontrollsysteme stellt sich daher insbes. die Frage nach der Auswahl geeigneter Entscheidungsobjekte und steuerungsrelevanter Kennzahlen. Letzteres bildet den Schwerpunkt der Beiträge, die in diesem Kapitel vorgestellt werden.

Der Beitrag „Ein formaler Ansatz zur Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge“ (Abschnitt 1) untersucht, wie der Nutzen von Kennzahlen quantifiziert werden kann und wie auf dieser Basis Kennzahlen ausgewählt werden können.

Der Beitrag “How to select measures for decision support systems – An optimization approach integrating informational and economic objectives” (Abschnitt 2) erweitert das im ersten Beitrag vorgestellte Auswahlverfahren zu einem Optimierungsmodell, sodass eine optimale Auswahl an Kennzahlen hinsichtlich informationeller und ökonomischer Ziele getroffen werden kann.

1 Beitrag: „Ein formaler Ansatz zur Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge“

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Erschienen in: Hansen HR, Karagiannis D, Fill HG (Hrsg)
Wirtschaftsinformatik 2009 - Business Services: Konzepte, Technologien, Anwendungen (Band 2), Wien

Zusammenfassung:

Ein noch immer nicht befriedigend gelöstes Problem bei der Gestaltung von Planungs- und Kontrollsystemen (PuK-Systemen) besteht in der Festlegung relevanter Inhalte, insbes. Kennzahlen. Als teilautomatisierte Ergänzung zu existierenden Ansätzen der Informationsbedarfsanalyse wird in diesem Beitrag ein formaler Algorithmus zur Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge für abgegrenzte Bereiche von PuK-Systemen entwickelt und anhand eines verein-fachten Beispiels angewendet.

1.1 Motivation und Forschungsgegenstand

Betriebliche Entscheidungsträger können aufgrund der komplexen inner- und außerbetrieblichen Strukturen nahezu unmöglich alle Problemfelder mit potenziellem Handlungsbedarf permanent überwachen (Gladen 2005; Gluchowski et al. 2008). Ein zentrales Problem bei der Einführung und Weiterentwicklung von PuK-Systemen liegt daher in der Auswahl von Entscheidungsobjekten und den zu deren Steuerung eingesetzten Kennzahlen. Hier sind die beschränkte kognitive Informationsverarbeitungskapazität von Entscheidungsträgern und konzeptionelle Limitationen, z. B. von Management Cockpits, Dashboards oder Balanced Scorecards, zu berücksichtigen (Kemper et al. 2006). Grundsätzliche Hilfestellungen bieten Ansätze der Informationsbedarfsanalyse wie die Methode der Kritischen Erfolgsfaktoren (Rockart 1979) oder vorgefertigte Bausteine („Templates“ / „Business Content“), z. B. in Systemen wie SAP® BI® (Mertens und Meier 2008).

Jedoch bestehen bez. der Auswahl von Kennzahlen, auf die sich dieser Beitrag konzentriert, noch Mängel; insbes. hinsichtlich einer intersubjektiven Nachvollziehbarkeit, der Partizipation von Entscheidungsträgern sowie der Berücksichtigung von Zusammenhängen zwischen Kennzahlen. Existierende Verfahren beruhen meist auf qualitativen Einschätzungen, was in der Praxis dazu führen kann, dass Auswahlentscheidungen bei der Gestaltung und „Entschlackung“ von Berichtssystemen überwiegend nach „Bauchgefühl“ getroffen werden, hoher personeller Aufwand durch Befragungen entsteht und viele Kennzahlen ausgewählt werden, deren Nutzen oft nebulös bleibt.

Innerhalb von Kennzahlensystemen unterscheidet Küpper (2005) logische, empirische und hierarchische Zusammenhänge. Logische entstehen durch Definition (z. B. Gewinn = Erträge – Aufwendungen) oder mathematische Transformation (z. B. ROI = Kapitalumschlag * Umsatzrendite). Empirische Zusammenhänge ergeben sich aus Beobachtung der Realität und sind deterministisch oder stochastisch (z. B. Zusammenhang zwischen Produktpreis und Absatzmenge). Hierarchische Zusammenhänge definieren Rangordnungen, die sachlich (z. B. Jahresgewinn = Summe der Monatsgewinne) oder subjektiv sein können (z. B. Liquidität ist wichtiger als Rentabilität).

Oft denkt man bei Kennzahlensystemen, wozu im weiteren Sinne auch Wertreiberbäume zählen, an baum- oder pyramidenartige Artefakte, in denen eine Spitzenkennzahl durch mathematische Transformationen hierarchisch-sachlich zerlegt wird. Jedoch sind logische und hierarchische Zusammenhänge ab einer bestimmten Zerlegungsstufe nicht mehr eindeutig (Küpper 2005), sodass die Existenz von Zusammenhängen durch Experten-befragung und deren Stärke durch Analyse von Vergangenheitsdaten empirisch ermittelt werden müssen. Wegen der fehlenden hierarchischen Struktur nennt man eine Zusammenfassung empirisch zusammenhängender Kennzahlen auch *Kennzahlennetz* (Gladen 2005). Während das hierarchische Kennzahlenteilsystem häufig monetäre und vergangenheitsorientierte Kennzahlen, wie z. B. Umsatz oder Deckungsbeitrag, umfasst, bestehen Kennzahlennetze auch aus nichtmonetären und z. T. zukunftsorientierten Kennzahlen, wie z. B. Anzahl der Vertriebsschulungen oder Kundenzufriedenheitsindizes. Wegen der fehlenden logischen und hierarchischen Struktur sind die Zusammenhänge innerhalb von Kennzahlennetzen tendenziell komplexer, was die Auswahl von Kennzahlen zusätzlich erschwert.

Somit stellt sich die Forschungsfrage: *Welche Kennzahlen sollen aus einem bestehenden Kennzahlennetz ausgewählt werden, um Entscheidungsträger über einen abgegrenzten betrieblichen Sachverhalt zweckmäßig zu informieren?*

Dem Beitrag liegt ein gestaltungsorientierter, formal-deduktiver Forschungsansatz zugrunde. Kapitel 1.2 stellt bisherige Arbeiten zur Kennzahlenauswahl einander gegenüber und arbeitet die Forschungslücke anhand eines Anforderungsgerüsts heraus. Kapitel 1.3 schlägt einen Ansatz zur Kennzahlenauswahl auf Basis empirischer Zusammenhänge vor. Dieser wird in Kapitel 1.4 anhand der Anforderungen aus Kapitel 1.2 und mithilfe eines vereinfachten Anwendungsbeispiels evaluiert. Kapitel 1.5 fasst die zentralen Ergebnisse zusammen, unterzieht diese einer kritischen Würdigung und gibt einen Ausblick auf weiteren Forschungsbedarf.

1.2 Bisherige Arbeiten zur Auswahl von Kennzahlen

Tab. III.1-1 Anforderungen an den Prozess der Kennzahlenauswahl

Anforderung	Erläuterung bez. des Prozesses der Kennzahlenauswahl
Vollständigkeit (R.1)	Alle zur Steuerung erforderlichen Kennzahlen werden ausgewählt.
Intersubjektivität (R.2)	Auswahlentscheidungen sind von Sachverständigen nachvollziehbar.
Klarheit (R.3)	Eine vom Menschen noch erfassbare begrenzte Menge von Kennzahlen wird systematisch, einheitlich und transparent strukturiert.
Multikausalität (R.4)	Zusammenhänge zwischen den Kennzahlen werden berücksichtigt.
Zielorientierung (R.5)	Der Bezug zu den oberen Unternehmenszielen wird berücksichtigt.
Partizipation (R.6)	Entscheidungsträger beeinflussen die Kennzahlenauswahl an definierten Stellen.

In der Literatur finden sich viele Anforderungen an Kennzahlensysteme, die auf Kennzahlennetze übertragbar sind. So sollten diese einen betrieblichen Sachverhalt vollständig abbilden (Vollständigkeit), intersubjektiv nachvollziehbar sein (Intersubjektivität), eine sinnvolle Ordnung und eine begrenzte Anzahl von Kennzahlen aufweisen (Klarheit), Zusammenhänge zwischen Kennzahlen explizieren (Multikausalität) sowie an den Unternehmenszielen ausgerichtet sein (Zielorientierung). Zudem sollten fachkundige Mitarbeiter eingebunden werden (Partizipation). Detaillierte Erläuterungen finden sich z. B. in (Gladen 2005; Reichmann 2006; Caplice und Sheffi 1995; Dinter und Bucher 2006). Die meisten dieser Anforderungen beziehen sich auf Kennzahlennetze als Artefakte und nicht auf den *Prozess* der Kennzahlenauswahl. Letzterer steht hier im Vordergrund, sodass sich die in Tab. III.1-1 aufgelisteten Anforderungen ergeben.

Zwischen den Anforderungen bestehen teils komplementäre, teils konfliktäre Beziehungen: z. B. verhalten sich Vollständigkeit und Klarheit konfliktär, Multikausalität und Klarheit komplementär. Zudem sind sie aufgrund ihrer natürlichsprachigen Formulierung mit Unschärfen behaftet. Dennoch bilden sie nach Einschätzung der Autoren eine nützliche Hilfestellung für die Evaluation bisheriger Ansätze und die Herausarbeitung der Forschungslücke. Ein Ansatz soll dabei im Sinne der o. g. Forschungsfrage als zweckmäßig gelten, wenn er die Anforderungen weitgehend erfüllt. Im Folgenden wird eine Auswahl von Quellen aus Fachzeitschriften und Lehrbüchern diskutiert, die konkrete Lösungsvorschläge, z. B. Vorgehensmodelle, beinhalten (siehe Tab. III.1-2).

Tab. III.1-2 Vergleich bestehender Ansätze zur Kennzahlenauswahl

Quellen	R.1	R.2	R.3	R.4	R.5	R.6
Liebetruth und Otto (2006)	Keine Aussage	Intersubjektivität durch formales Modell	Keine Strukturierung; subjektive Festlegung der Kennzahlen-obergrenze	Isolierte Betrachtung	Zielbezug über Wert-treiber	Partizi-pation über Vergabe von Nutzwerten
Neely et al. (1995)	Keine Aussage	Eingeschränkte Intersubjektivität über Checklisten	Keine Strukturierung; keine Kennzahlen-obergrenze	Eigener Prozessschritt, nicht konkretisiert	Zielbezug über Unter-nehmens-strategie	Keine Aussage
Reichmann (2006)	Keine Aussage	Keine Aussage	Keine Strukturierung; Forderung nach hoher Informations-dichte	Isolierte Betrachtung	Kein expliziter Zielbezug	Keine Aussage
Rockart (1979)	Keine Aussage	Subjektive Zuordnung von Kennzahlen zu Erfolgsfaktoren	Strukturierung über Erfolgsfaktoren; keine Kennzahlenobergrenze	Isolierte Betrachtung	Zielbezug über Erfolgs-faktoren	Partizi-pation über explorative Interviews
Weber (1995)	„Operative“ und „strategische“ Kennzahlen	Subjektivität durch Thesen-abgabe	Strukturierung über Erfolgsfaktoren; keine Kennzahlenobergrenze	Isolierte Betrachtung	Zielbezug über Erfolgs-faktoren	Partizi-pation durch Thesen-abgabe

Liebetruth und Otto (2006) präsentieren ein lineares Optimierungsmodell, das aus einer gegebenen Kennzahlenmenge eine nutzenmaximale Teilmenge auswählt. Neely et al. (1995) fordern eine Auswahl von Kennzahlen unter Kosten-Nutzen-Gesichtspunkten. Reichmann (2006) versucht, Kennzahlen mit dem Ziel einer hohen „Informations-verdichtung“ auszuwählen. Rockart (1979) erläutert im Rahmen der Methode der Kritischen Erfolgsfaktoren, wie der subjektive Informationsbedarf von Entscheidungs-trägern auf wenige essentielle Handlungsfelder eingrenzbar ist. Jedem Erfolgsfaktor werden in Interviews Kennzahlen zugeordnet. Weber (1995) schlägt mit dem Konzept der selektiven Kennzahlen einen Ansatz vor, in dem Kennzahlen aus von Entscheidungs-trägern abgegebenen Thesen abgeleitet werden.

Besonders auffällig ist, dass lediglich der Ansatz von Liebetruth und Otto aufgrund des formalen Modells intersubjektiv nachvollziehbar (R.2) ist. Gleichzeitig erlaubt nur er die Festlegung einer Kennzahlenobergrenze (R.3). Kein Ansatz berücksichtigt Zusammen-hänge zwischen Kennzahlen (R.4). Entscheidungsträger haben kaum definierte Eingriffs-punkte (R.6). Folglich lässt sich insbesondere hinsichtlich der Anforderungen Intersubjektivität (R.2), Klarheit (R.3), Multikausalität (R.4) und Partizipation (R.6) eine Forschungslücke identifizieren.

1.3 Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge

Die Idee des vorgeschlagenen Ansatzes wird zunächst konzeptionell vorgestellt und anhand eines Beispiels veranschaulicht.

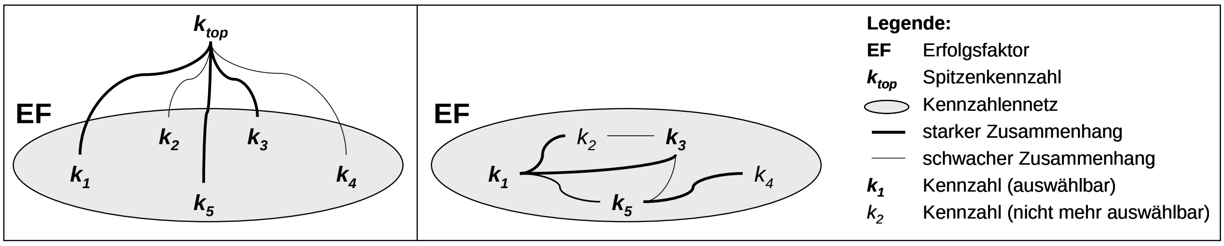

Abb. III.1-1 Zusammenhänge innerhalb eines Kennzahlennetzes und mit der Spitzenkennzahl

Wir gehen – analog zu existierenden Ansätzen – davon aus, dass der Informationsbedarf eines Entscheidungsträgers im Rahmen einer Erfolgsfaktorenanalyse vorstrukturiert wurde und für jeden Erfolgsfaktor eine Menge potenziell sinnvoller Kennzahlenkandidaten in Form eines Kennzahlennetzes vorliegt. Abb. III.1-1 zeigt einen Erfolgsfaktor mit einem Kennzahlennetz bestehend aus fünf Kennzahlen k_1 bis k_5. Zwischen den Kennzahlen bestehen empirische Zusammenhänge, wobei hier vereinfachend nur „stark“ und „schwach“ unterschieden werden. So existiert z. B. zwischen k_1 und k_2 ein starker, zwischen k_1 und k_5 ein schwacher und zwischen k_1 und k_4 kein (direkter) Zusammenhang. Jede Kennzahl beeinflusst zudem die Spitzenkennzahl des Unternehmens k_{top}; z. B. k_1 stark, k_2 schwach. Für den Erfolgsfaktor stellt sich die Frage, welche Kennzahlen ausgewählt werden sollen. Der Mehrwert des Ansatzes ergibt sich v. a. durch Anwendung für mehrere Erfolgsfaktoren.

Empirische Zusammenhänge werden in zweierlei Hinsicht genutzt: Denjenigen mit k_{top} kommt eine initiale Filterfunktion zu, d. h. nur solche Kennzahlen sind später auswählbar, die stark auf k_{top} wirken. Im Beispiel würden k_2 und k_4 nicht weiter betrachtet. Anhand der Zusammenhänge innerhalb des Kennzahlennetzes werden die Kennzahlen ausgewählt, die gemeinsam möglichst stark mit vielen anderen Kennzahlen zusammenhängen. Denn je stärker zwei Kennzahlen zusammenhängen, desto zuverlässiger lässt sich der Wert der einen bei Kenntnis der anderen schätzen. Um solche Kennzahlen unter der gegebenen Anzahlrestriktion zu selektieren, wird nach dem Prinzip des abnehmenden Grenzzusammenhangs – analog zum abnehmenden Grenznutzen (Varian 2007) – vorgegangen, d. h. jeweils die Kennzahl mit dem stärksten zusätzlichen Zusammenhang wird als nächste gewählt. Im Beispiel sollen zwei Kennzahlen gewählt werden. Im zweiten Schritt sind k_1, k_3 und k_5 auswählbar. Als erste Kennzahl würde k_1 berücksichtigt, weil sie durch die starken Zusammenhänge mit k_2 und k_3 sowie den schwachen Zusammenhang mit k_5 die initial stärkste Einbettung aufweist. Bei der Wahl der zweiten Kennzahl ist der Grenzzusammenhang zu betrachten: Für k_5 umfasst dieser den starken Zusammenhang mit k_4 sowie die Differenz zwischen dem schwachen Zusammenhang k_1 mit k_5 und dem perfekten Zusammenhang von k_5 mit sich selbst (Autokorrelation). Der Zusammenhang mit k_1 zählt nicht, da k_1 bereits bekannt ist. Der Zusammenhang mit k_3 zählt nicht, da zwischen k_1 und k_3 ein stärkerer Zusammenhang besteht. Der Grenzzusammenhang von k_3 resultiert lediglich aus der Differenz zwischen dem starken Zusammenhang k_1 mit k_3 und dem perfekten Zusammenhang von k_3 mit sich selbst (Autokorrelation). Die Zusammenhänge mit k_1, k_2 und k_5 werden durch k_1 abgedeckt. Wegen des höheren Grenzzusammenhangs wird k_5 als zweite Kennzahl gewählt.

Die Güte einer Kennzahl hängt naturgemäß nicht nur von ihrer empirischen Einbettung ab. Manche Kennzahlen sind z. B. verhältnismäßig einfach aus einem operativen System extrahierbar, andere müssen personell erfasst und aufbereitet werden. Solch basale Anforderungen beeinflussen die Güte der auszuwählenden Kennzahlen und sind daher ebenfalls zu berücksichtigen. Im vorgeschlagenen Ansatz geschieht das im Folgenden, indem von zwei Kennzahlen mit gleich starkem (Grenz-) Zusammenhang diejenige bevorzugt wird, welche die basalen Anforderungen besser erfüllt.

Zur rechnerischen Verknüpfung des (Grenz-) Zusammenhangs mit dem Erfüllungsgrad basaler Anforderungen und um Präferenzen hinsichtlich einzelner Kennzahlen ausdrücken zu können, liegt – analog zu Liebetruth und Otto – das Konzept des ordinalen Nutzens zugrunde (Varian 2007). Aus Konsistenzgründen wird auch der Zusammenhang mit der Spitzenkennzahl als Nutzen ausgedrückt.

Im Folgenden werden in Kapitel 1.3.1 und 1.3.2 zunächst die Annahmen des Ansatzes dargelegt und eine Formalisierung der drei Nutzenkomponenten vorgeschlagen. In Kapitel 1.3.3 wird das eben skizzierte Vorgehen in einen Algorithmus überführt.

1.3.1 Annahmen

A.1 Gegeben seien eine Menge von Kennzahlen $K = \{k_1, k_2, ..., k_m\}$ und eine Spitzenkennzahl k_{top} als metrisch skalierte Merkmale. K ist ein Kennzahlennetz. Zwischen manchen Kennzahlen bestehen unmittelbare, paarweise, symmetrische und sinnvoll interpretierbare empirische Zusammenhänge. Diese seien durch eine $m \times m$-Matrix C^K repräsentiert. Dabei steht c_{ij} für die Stärke des Zusammenhangs zwischen k_i und k_j mit $c_{ij} = 0$ genau dann, wenn k_i und k_j unabhängig sind bzw. deren Zusammenhang nicht sinnvoll interpretiert werden kann ($1 \leq i, j \leq m, i \neq j$). Jede Kennzahl k_i hängt mit k_{top} unmittelbar, paarweise und symmetrisch empirisch zusammen. Die Zusammenhänge mit k_{top} seien durch einen m-elementigen Vektor $\vec{C}^{k_{top}}$ repräsentiert.

A.2 Alle empirischen Zusammenhänge seien im betrachteten Zeitraum approximativ linear und konstant. Der betrachtete Zeitraum umfasst den Zeitraum, auf dessen Grundlage die Stärke der Zusammenhänge ermittelt wird, und den Zeitraum, in dem Berichte auf Basis der ausgewählten Kennzahlen verwendet werden.

A.3 Eine Kennzahl k_i stifte Nutzen. Dabei soll gelten: Je besser k_i basale Anforderungen erfüllt, desto mehr Nutzen stiftet sie. Je stärker k_i mit k_{top} zusammenhängt, desto mehr Nutzen stiftet sie. Wurde noch keine Kennzahl gewählt, so gilt: Je stärker k_i mit den anderen Kennzahlen aus K zusammenhängt, desto mehr Nutzen stiftet sie. Wurde bereits mindestens eine Kennzahl gewählt, so gilt: Je stärker k_i mit solchen Kennzahlen zusammenhängt, mit denen die bisher gewählten Kennzahlen nicht oder schwächer zusammenhängen, desto mehr (Grenz-) Nutzen stiftet sie.

Den empirischen Zusammenhängen aus A.1 geht eine Validierung im Sinne einer sinnvollen Interpretierbarkeit durch Domänenexperten voraus. Dies ist sinnvoll, weil eine ausschließliche Untersuchung statistischer Zusammenhänge aufgrund von Scheinkorrelationen zu falschen Interpretationen führen mag. Prominente Beispiele hierfür finden sich u. a. in (Hilbert 1998). Vereinfachend werden Zusammenhänge zwischen mehr als zwei Kennzahlen und transitive Zusammenhänge nicht betrachtet; genauso wie exogene dritte Einflussgrößen. Obwohl in der betrieblichen Realität durchaus asymmetrische Zusammenhänge im Sinne von Ursache und Wirkung vorkommen, werden hier im Rahmen einer Interdependenzanalyse vereinfachend symmetrische Zusammenhänge angenommen. Damit lassen sich einfachere und verständlichere Zusammenhangsmaße nutzen. Die in A.2 unterstellte Linearität ist vertretbar, da sie für viele ökonomische Anwendungsfälle eine hinreichend gute Approximation für nichtlineare Zusammenhänge darstellt (Rönz und Förster 1992) – insbesondere bei abgegrenztem Untersuchungszeitraum. A.3 wurde bereits durch die konzeptionelle Erläuterung oben motiviert.

Aufgrund der Annahmen lässt sich die Zusammenhangsmatrix C^K wie folgt befüllen: Im Rahmen der Erfolgsfaktorenanalyse wird ermittelt, zwischen welchen Kennzahlen aus K ein sinnvoll interpretierbarer Zusammenhang besteht. Die Stärke (nur) dieser Zusammenhänge wird auf Basis von Vergangenheitswerten anhand des Bravais-Pearson-Korrelationskoeffizienten r, einem in der Statistik häufig eingesetzten Maß für lineare Zusammenhänge, bestimmt. Allerdings reichen die Absolutbeträge aus, da nach A.3 lediglich die Stärke, nicht die Richtung, relevant ist. Der zweite Schritt gilt analog für den Zusammenhangsvektor $\vec{C}^{k_{top}}$.

1.3.2 Formalisierung der Nutzenkomponenten

Jeder Kennzahl sind drei Nutzenkomponenten zugeordnet: Nutzen durch Zusammenhang mit der Spitzenkennzahl, Nutzen durch Zusammenhang mit anderen Kennzahlen aus K und Basisnutzen. Diese werden hier formal eingeführt, die Art ihres Zusammenwirkens in Kapitel 3.3.

Nutzen durch Zusammenhang mit der Spitzenkennzahl

Zunächst wird der Nutzen $U_{k_i}^{k_{top}}$ durch Zusammenhang einer Kennzahl k_i mit der Spitzenkennzahl k_{top} formalisiert. Dadurch kann k_i später aussortiert werden, falls diese eine definierte Untergrenze unterschreitet. Nach A.3 ist der Nutzen umso höher, je stärker dieser Zusammenhang ist. Die betragsmäßigen Korrelationskoeffizienten des Zusammenhangsvektors $\vec{C}^{k_{top}}$ erfüllen diese Bedingung, sodass $U_{k_i}^{k_{top}}$ dem i-ten Element gleichgesetzt werden kann.

Nutzen durch Zusammenhang mit anderen Kennzahlen

Der Nutzen $\vec{U}_{k_i}^{K}$ durch Zusammenhang einer einzelnen Kennzahl k_i mit den anderen Kennzahlen aus K lässt sich als Vektor darstellen und kann nach A.3 dem i-ten Spaltenvektor von C^K gleichgesetzt werden. Die isolierte Betrachtung einer Kennzahl ist nur bei der Wahl der ersten Kennzahl aussagekräftig. Die interessantere Frage lautet, welchen Grenznutzen $\Delta\vec{U}_{k_i|K_{selected}}^{K}$ eine Kennzahl k_i stiftet, wenn bereits eine Menge von Kennzahlen $K_{selected}$ gewählt wurde. Zunächst mag die Differenz $\vec{U}_{k_i}^{K} - \vec{U}_{K_{selected}}^{K}$ zur Formalisierung des Grenznutzens geeignet erscheinen. Falls k_i mit einer anderen Kennzahl k_j schwächer zusammenhängt als die Kennzahlen aus $K_{selected}$, würde sich der Nutzen diesbez. dann jedoch verschlechtern. Das ist unplausibel, weil auf die bisher gewählten, stärker mit k_j zusammenhängenden Kennzahlen aus $K_{selected}$ zurückgegriffen werden kann. Folglich muss der Grenznutzen durch die Hinzunahme von k_i mindestens null sein. Für $\Delta\vec{U}_{k_i|K_{selected}}^{K}$ ergibt sich mit $u_{K_{selected},k_j}^{K}$ als Nutzen durch Zusammenhang der bisher gewählten Kennzahlen mit k_j:

$$\Delta\vec{U}_{k_i|K_{selected}}^{K} = \begin{pmatrix} \max\left(\left|r_{k_i,k_1}\right| - u_{K_{selected},k_1}^{K}, 0\right) \\ \max\left(\left|r_{k_i,k_2}\right| - u_{K_{selected},k_2}^{K}, 0\right) \\ \ldots \\ \max\left(\left|r_{k_i,k_2}\right| - u_{K_{selected},k_m}^{K}, 0\right) \end{pmatrix} \tag{III.1-1}$$

Soll der Grenznutzen als Skalar ausgedrückt und in jedem Auswahlschritt auf das Intervall [0;1] normiert werden, so ergibt sich folgende Formel. Der Nenner gibt dabei an, welcher maximale Grenznutzen bez. $K_{selected}$ möglich ist.

$$\Delta U_{k_i|K_{selected},norm.}^{K} = \frac{\vec{1}^T \cdot \Delta\vec{U}_{k_i|K_{selected}}^{K}}{\sum_{o=1}^{m}\left(1 - u_{K_{selected},k_o}^{K}\right)} = \frac{\sum_{l=1}^{m}\max\left(\left|r_{k_i,k_l}\right| - u_{K_{selected},k_l}^{K}, 0\right)}{\sum_{o=1}^{m}\left(1 - u_{K_{selected},k_o}^{K}\right)} \tag{III.1-2}$$

Wird k_i gewählt, so ergibt sich für $\vec{U}^{K}_{K_{selected} \cup k_i}$:

$$\vec{U}^{K}_{K_{selected} \cup k_i} = \vec{U}^{K}_{K_{selected}} + \Delta\vec{U}^{K}_{k_i | K_{selected}} \qquad \text{(III.1-3)}$$

Basisnutzen

Der Basisnutzen $U^{basis}_{k_i}$ einer Kennzahl k_i gibt an, wie „gut“ diese eine vorgegebene Menge von basalen Anforderungen $A = \{A.1, A.2, ..., a_z\}$ erfüllt. Beispiele für solche Anforderungen sind Beeinflussbarkeit, Verständlichkeit, Messbarkeit und Manipulationsfreiheit (Gladen 2005). Über die Anforderungen lassen sich positive wie negative Effekte bewerten. So gibt ein hoher Wert für Verständlichkeit an, dass eine Kennzahl intuitiv interpretierbar ist. Ein niedriger Wert für Messbarkeit hingegen zeigt, dass die Verwendung der Kennzahl mit hohem Erhebungsaufwand verbunden ist. Es wird daher darauf verzichtet, dem Nutzen einer Kennzahl Kosten explizit gegenüber zu stellen, zumal diese einer Kennzahl im Sinne des Identitätsprinzips kaum verursachungsgerecht zuordenbar sind. Jeder Kennzahl wird für jede Anforderung über eine Funktion $Score_{basis}$: $K \times A \rightarrow [0;1]$ ein Wert aus dem Intervall [0;1] zugeordnet. Die Ermittlung dieser Funktion erfolgt vor der Kennzahlenauswahl z. B. auch bei einer Erfolgsfaktorenanalyse und ist nicht Bestandteil dieses Ansatzes. Des Weiteren bietet es sich an, den Basisnutzen mittels Division durch die Anzahl der basalen Anforderungen z auf das Intervall [0;1] zu normieren, um dessen Interpretierbarkeit und Vergleichbarkeit über Auswahlvorgänge mit unterschiedlicher Anzahl von Anforderungen zu gewährleisten. Daraus ergibt sich:

$$U^{basis}_{k_i} = \frac{\sum_{l=1}^{z} Score_{basis}(k_i, a_l)}{z} \qquad \text{(III.1-4)}$$

1.3.3 Algorithmus zur Kennzahlenauswahl

Der Algorithmus verknüpft die Nutzenkomponenten in zwei Schritten (siehe Abb. III.1-2). Hilfsvariablen sind $K_{residual}$ und $K_{selected}$: erstere umfasst die Menge der noch zur Auswahl stehenden Kennzahlen und entspricht initial K, zweitere beinhaltet die bereits ausgewählten Kennzahlen in Form einer Liste und ist initial leer. Die Listeneigenschaft ermöglicht die Bildung einer Kennzahlen-Rangfolge nach abnehmendem Grenznutzen.

Im ersten Schritt werden sämtliche Kennzahlen aussortiert, deren Nutzen durch Zusammenhang mit der Spitzenkennzahl eine definierte Untergrenze $U_{MIN}^{k_{top}}$ unterschreitet. Im zweiten Schritt werden Kennzahlen mit einer Kombination aus beschränkter Tiefensuche und Bestensuche ausgewählt (Russell und Norvig 2004). Die beschränkte Tiefensuche bricht den Suchvorgang ab, nachdem eine definierte Obergrenze von Kennzahlen $|K_{selected}|_{MAX}$ erreicht wurde. Die Bestensuche mit Greedy-Heuristik wählt jeweils die Kennzahl mit dem höchsten Grenznutzen als nächste aus. Dies erscheint sinnvoll, weil das Kennzahlenauswahlproblem analog dem Rucksackproblem ist, welches anhand der Greedy-Heuristik approximativ lösbar ist (Dempe und Schreier 2006). Dabei soll eine nutzenmaximale Menge verschiedener Gegenstände in einen Rucksack aufgenommen werden, wobei jeder Gegenstand unterschiedlich schwer ist, einen unterschiedlich hohen Nutzen stiftet und insgesamt eine Gewichtsobergrenze nicht überschritten werden darf. Die Analogie besteht darin, dass hier eine nutzenmaximale Menge verschiedener Kennzahlen in ein Kennzahlennetz aufgenommen werden soll, wobei jede Kennzahl gleich „schwer“ ist, unterschiedlich hohen Nutzen stiftet und eine Obergrenze $|K_{selected}|_{MAX}$ nicht überschritten werden darf.

Der zweite Schritt läuft im Detail wie folgt ab: Für jede Kennzahl $k_i \in K_{residual}$ wird der Grenznutzen bestimmt, indem man den Grenznutzen durch Zusammenhang mit den anderen Kennzahlen und den Basisnutzen addiert. Der isolierte Nutzen für die Auswahl der ersten Kennzahl lässt sich als Grenznutzen bez. der leeren Menge ($\emptyset$) darstellen. Der Basisnutzen fließt immer voll ein, da er nicht von den zuvor gewählten Kennzahlen abhängt. Der additiven Verknüpfung liegt die Idee zugrunde, dass Basisnutzen und Nutzen durch Zusammenhang mit anderen Kennzahlen substituierbar sind (Varian 2007). Beide Summanden liegen stets zwischen [0;1] und werden mit α bzw. $(1 - \alpha)$ mit $0 \leq \alpha \leq 1$ gewichtet, damit sie unterschiedlich stark einfließen können. In jedem Auswahlschritt wird die Kennzahl mit dem höchsten Grenznutzen aus $K_{residual}$ entfernt und zu K_{selected} hinzugefügt (mit „+“ als Listen-Einfügeoperator). Sollte es mehrere Kennzahlen mit gleich hohem Nutzen geben, so bietet sich bspw. an, eine zu wählen, für die andere(n) einen erneuten Suchlauf durchzuführen und schließlich die Kennzahlenliste mit dem höchsten Gesamtnutzen zu verwenden. Darüber hinaus mag man Kennzahlen vorgeben, die aus Sicht der Entscheidungsträger zwingend zu berücksichtigen sind. Der

Algorithmus terminiert sobald $|K_{selected}|_{MAX}$ erreicht wurde und/oder keine weitere Kennzahl mehr zur Verfügung steht. K_{selected} enthält dann die ausgewählten Kennzahlen aufgelistet nach abnehmendem Grenznutzen.

/* Initialisierung */
$K_{residual} \leftarrow K$
$K_{selected} \leftarrow \varnothing$

/* Schritt 1: Auswahl bez. Nutzen durch Zusammenhang mit der Spitzenkennzahl */
Für alle $k_i \in K_{residual}$: Wenn $U_{k_i}^{k_{top}} < U_{MIN}^{k_{top}}$ Dann $K_{residual} \leftarrow K_{residual} \setminus \{k_i\}$

/* Schritt 2: Auswahl bez. Nutzen durch Zusammenhang im Kennzahlennetz und Basisnutzen */
Solange ($|K_{selected}| < |K_{selected}|_{MAX}$ und $|K_{residual}| > 0$) {
  Für alle $k_i \in K_{residual}$: Berechne $\Delta U_{k_i|K_{selected}} = \alpha \cdot \Delta U^{K}_{k_i|K_{selected},norm.} + (1-\alpha) \cdot U_{k_i}^{basis}$
  Wähle k_i mit dem höchsten $\Delta U_{k_i|K_{selected}}$
    $K_{residual} \leftarrow K_{residual} \setminus \{k_i\}$
    $K_{selected} \leftarrow K_{selected} + k_i$
}

Abb. III.1-2 Algorithmus zur Kennzahlenauswahl

1.4 Evaluation und Anwendungsbeispiel

Der Ansatz hatte zum Ziel, die Forschungslücke bez. der Anforderungen Intersubjektivität (R.2), Klarheit (R.3), Multikausalität (R.4) und Partizipation (R.6) aus Kapitel 2 zu schließen: Durch die formale Darstellung der Nutzenkomponenten und des Algorithmus sind Vorgehen und Bewertungskriterien intersubjektiv nachvollziehbar. Während die korrelationsbasierten Nutzenkomponenten weitgehend frei von subjektiven Einflüssen sind, hängt der Basisnutzen von der Expertise der Entscheidungsträger ab (R.2). Empirische Zusammenhänge mit der Spitzenkennzahl haben eine initiale Filterfunktion, Zusammenhänge innerhalb des Kennzahlennetzes dienen der Kennzahlenauswahl derart, dass möglichst zuverlässige Schätzungen der anderen Kennzahlen möglich sind (R.4). Zudem ist die Anzahl der Kennzahlen im Sinne der Klarheit (R.3) begrenzt. Entscheidungsträger können über definierte „Stellschrauben“ – wie z. B. Kennzahlenobergrenze, Mindestnutzen durch Zusammenhang mit der Spitzenkennzahl, Gewichtungsparameter α, Vorgabe von Kennzahlen – die Kennzahlenauswahl systematisch und nachvollziehbar beeinflussen (R.6). Der Ansatz leistet somit einen gewissen Beitrag zur Schließung der identifizierten Forschungslücke.

Um die Anwendbarkeit des Ansatzes zu zeigen, wird das eingangs konzeptionell eingeführte Beispiel nochmals aufgegriffen. Dieses Mal werden nicht nur „starke“ und „schwache“ Zusammenhänge unterschieden, sondern die in Abb. III.1-3 links dargestellten Werte zugrunde gelegt. Nun wird auch der Basisnutzen berücksichtigt, in den analog zu oben vereinfachend nur die Erhebbarkeit (*A.1*) einfließt; bspw. ist k_3 einfach zu erheben, k_5 schwer. Nach wie vor sind zwei Kennzahlen zu wählen, d. h. $|K_{selected}|_{MAX} = 2$. Zudem soll der Nutzen durch Zusammenhang mit anderen Kennzahlen stärker gewichtet werden als der Basisnutzen; daher $\alpha = 0{,}7$. Der Mindestnutzen durch Zusammenhang mit der Spitzenkennzahl sei $U_{MIN}^{k_{top}} = 0{,}7$. Im ersten Schritt werden k_2 und k_4 aussortiert, da sie diesen Mindestnutzen unterschreiten. Folglich sind k_1, k_3 und k_5 im zweiten Schritt auswählbar. Der detaillierte Ablauf lässt sich anhand der textuellen Ausgabe eines bereits implementierten Prototyps in Abb. III.1-3 rechts nachvollziehen: k_1 stiftet den höchsten initialen Nutzen und wird als erste Kennzahl ausgewählt. Man erkennt, dass k_1 eine stärkere empirische Einbettung, jedoch einen geringeren Basisnutzen aufweist als k_3. Aufgrund der Wahl von α ist der Gesamtnutzen von k_1 – wenn auch nur geringfügig – höher als der von k_3. Für die Wahl der zweiten Kennzahl stehen k_3 und k_5 zur Verfügung. Hier zeigt sich die Grenznutzenbetrachtung. Während k_3 und k_5 vor der Auswahl von k_1 noch denselben Nutzen durch empirische Einbettung stiften, ergeben sich diesbez. nun Unterschiede. k_5 stiftet hier zwar höheren Grenznutzen durch empirische Einbettung, jedoch wesentlich geringen Basisnutzen als k_3. Dieser wird nicht durch die stärkere empirischer Einbettung kompensiert, sodass k_3 als zweite Kennzahl gewählt wird. Dieses Ergebnis stimmt aufgrund des nun zusätzlich berücksichtigten Basisnutzens nicht mit dem des eingangs skizzierten Beispiels überein.

U^K	k_1	k_2	k_3	k_4	k_5
k_1	**1,00**	0,90	0,51	0,00	0,25
k_2	0,90	**1,00**	0,30	0,00	0,00
k_3	0,51	0,30	**1,00**	0,00	0,30
k_4	0,00	0,00	0,00	**1,00**	0,55
k_5	0,25	0,00	0,30	0,55	**1,00**

U^{ktop}	k_{top}
k_1	0,80
k_2	0,30
k_3	0,70
k_4	0,40
k_5	0,70

U^{basis}	a_1
k_1	0,80
k_2	0,60
k_3	1,00
k_4	0,60
k_5	0,20

Es gilt: $|K_{selected}|_{MAX} = 2$; $U_{MIN}^{k_{top}} = 0{,}7$; $\alpha = 0{,}7$

```
Select figure #1
------------------
Utility of k1 = 0.7 * 0.53 + 0.3 * 0.8 = 0.61
Utility of k3 = 0.7 * 0.42 + 0.3 * 1.0 = 0.59
Utility of k5 = 0.7 * 0.42 + 0.3 * 0.2 = 0.35
==> Figure k1 has been selected!

Select figure #2
------------------
Utility of k3 = 0.7 * 0.23 + 0.3 * 1.0 = 0.46
Utility of k5 = 0.7 * 0.56 + 0.3 * 0.2 = 0.45
==> Figure k3 has been selected!
```

Abb. III.1-3 Nutzentabellen und Ausschnitt der Ausgabe eines Prototyps

Zusammenfassend lässt sich festhalten, dass die vorgeschlagene Formalisierung die eingangs entwickelte Idee zur Kennzahlenauswahl geeignet umsetzt und zu konsistenten Auswahlentscheidungen führt.

1.5 Zusammenfassung, kritische Würdigung und Ausblick

Der vorgeschlagene Ansatz dient der Auswahl von Kennzahlen auf Basis empirischer Zusammenhänge. Ziel war es, auf den Ergebnissen einer Erfolgsfaktorenanalyse aufbauend aus einem gegebenen Kennzahlennetz diejenigen Elemente auszuwählen, die gemeinsam einen Entscheidungsträger zweckmäßig informieren. Dazu werden Kennzahlen anhand von drei Nutzenkomponenten bewertet und in einem zweistufigen Algorithmus nach abnehmendem Grenznutzen ausgewählt. Die Nutzenkomponenten drücken aus, wie „gut“ eine Kennzahl basale Anforderungen – z. B. Erhebbarkeit – erfüllt, wie stark – gemessen über den Bravais-Pearson-Korrelationskoeffizienten – sie mit den anderen Kennzahlen des Kennzahlennetzes bzw. mit der Spitzenkennzahl des Unternehmens zusammenhängt. Aktuell ist der Ansatz prototypisch implementiert und konnte im Rahmen zweier Kooperationsprojekte mit Unternehmen aus der Telekommunikations- und der Elektrobranche erstmals angewandt werden. Folgende Erweiterungen sind geplant:

1. Der Begriff des Zusammenhangs beschränkt sich auf direkte, paarweise und symmetrische Beziehungen zwischen Kennzahlen. Künftig soll untersucht werden, welche dieser Restriktionen aufgehoben und in den Ansatz integriert werden können.

2. Der Algorithmus unterliegt den Einschränkungen einer Bestensuche auf Basis der Greedy-Heuristik (Dempe und Schreier 2006). Demnach werden nicht zwingend die Kennzahlen mit dem global höchsten Gesamtnutzen gewählt. Dieses Problem könnte durch eine Breitensuche vermieden werden, was zu einem Verlust der Rangordnung im Sinne des abnehmenden Grenznutzens führen würde. Zudem ist das Abbruchkriterium über die Kennzahlenobergrenze exogen vorgegeben, was ebenfalls zu suboptimalen Entscheidungen führen kann. Bspw. ist es möglich, dass der Erhebungsaufwand einer weiteren Kennzahl den Grenznutzen ökonomisch nicht rechtfertigt. Benötigt wird also eine Trade-Off-Betrachtung. Es ist geplant, den Algorithmus hinsichtlich beider genannter Probleme zu erweitern.

3. Ferner gilt es, den Ansatz mit bestehenden Methoden der Informationsbedarfsanalyse formal zu verknüpfen, zusätzliche strukturierende Elemente (z. B. die Perspektiven der Balanced Scorecard) zu berücksichtigen und – mit Blick auf Analytische Informationssysteme – um einen Ansatz zur Auswahl von Dimensionselementen (Entscheidungsobjekten) zu erweitern.

4. Des Weiteren ist zu untersuchen, wie logisch und hierarchisch zusammenhängende Kennzahlen berücksichtigt werden können.

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2 Beitrag: „How to select measures for decision support systems – An optimization approach integrating informational and economic objectives“

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Erschienen in:	Proceedings of the 17th European Conference on Information Systems, Verona

Abstract:

It is still an open issue of designing and adapting (data-driven) decision support systems and data warehouses to determine relevant content and in particular (performance) measures. In fact, some classic approaches to information requirements determination such as Rockart's critical success factors method help with structuring decision makers' information requirements and identifying thematically appropriate measures. In many cases, however, it remains unclear which and how many measures should eventually be used. Therefore, an optimization model is presented that integrates informational and economic objectives. The model incorporates (statistic) interdependencies among measures – i. e. the information they provide about one another –, decision makers' and reporting tools' ability of coping with information complexity as well as negative economic effects due to measure selection and usage. We show that in general the selection policies of all-or-none or the-more-the-better are not reasonable although they are often conducted in business practice. Finally, the model's application is illustrated by the German business-to-business sales organization of a global electronics and electrical engineering company as example.

2.1 Motivation and object of research

Due to the complexity of intra- and extraorganizational structures, it is impossible for decision makers in general – and executives in particular – to continuously monitor all fields of action that possibly require intervention. With reports containing in average up to 15,000 data points based on measures, i. e. key figures or (performance) indicators, information proliferation makes it even harder to focus on decision-relevant information (Axson 2007). Some measures more or less significantly influence the complexity of reports and the amount of time needed to understand them. The number of measures also drives the costs for customizing and maintaining reports. Hence, a central problem in the design and adaptation of (data-driven) decision support systems (DSS) and data warehouses (Alter 1980; Inmon 2005) still is to determine relevant fields of action and to select appropriate measures (Eccles 1991; Watson and Frolick 1993). Particularly the latter requires formal research (Evans 2004).

Some classic approaches to information requirements determination (IRD), such as Rockart's critical success factors (CSFs) method (1979), provide valuable assistance with structuring decision makers' information requirements (IR) and identifying thematically appropriate measures. However, these measures are often too many and it is unclear which should eventually be used. In this respect, decision makers' cognitive restrictions (Browne and Ramesh 2002; Davis 1982), limitations of reporting tools such as management cockpits and dashboards (Sisfontes-Monge 2007), and negative monetary implications need to be considered. As for measure selection in particular, there are additional deficiencies with respect to whether the selection process is intersubjectively comprehensible, decision makers can participate systematically, and (statistic) interdependencies among measures (e. g. quantifiable by means of correlation or contingency coefficients) are considered. In business practice, these deficiencies can result in that measure selection is based on "gut instinct", that many time-consuming interviews are conducted, and that the utility of selected measures remains doubtful. Therefore, the research question is: *Which and how many measures shall be selected from a preselected set of thematically appropriate measures in order to provide decision makers with optimal information as regards informational and economic objectives?*

The paper relies on a design-oriented, formal, and deductive approach (Hevner et al. 2004). Section 2.2 compares existing approaches with respect to general requirements and identifies the research gap. Section 2.3 proposes an optimization model as artifact. Section 2.4 evaluates the optimization model by illustrating its application in business practice and by assessing how it meets the general requirements outlined above. Section 2.5 summarizes the results and points out future research.

2.2 Related work

Currently, measures are often contained in performance measurement systems (PMS). In management accounting and operations management literature, there is a range of requirements on PMS (e. g. Caplice and Sheffi 1995; Neely et al. 1995). Accordingly, PMS are expected to capture all relevant constituencies of a specific field of action (*completeness,* R.1), to encompass a manageable amount of measures (*clarity,* R.2), and to transfer the overall business strategy to decision makers (*vertical integration,* R.3). The process of measure selection should be intersubjectively comprehensible (*intersubjectivity,* R.4), consider (statistic) interdependencies among measures (*interdependencies,* R.5), and involve domain experts (*participation,* R.6). Although the requirements are somehow vague due to prosaic formulation, the author considers that they provide basic assistance with comparing existing approaches and with identifying the research gap (see Tab. III.2-1 where completeness is omitted as it is not addressed by any approach).

In the following, selected approaches from international journals and textbooks are presented. Due to space restrictions, this is done briefly. Giorgini et al. (2008) present a goal-oriented approach to determine IR for data warehouses that considers the organizational environment and decision makers' needs. Neely et al. (2000) advocate a selection of measures in terms of a cost-benefit-analysis. Liebetruth and Otto (2006) present a linear optimization model with which a utility-optimal subset of measures can be chosen from a set of preselected and thematically appropriate measures. Rockart (1982) shows how decision makers' IR can be structured and reduced to a few essential fields of action, the so-called CSFs, each of which is monitored by several measures (see also Leidecker and Bruno (1984)). Axson (2007) extends CSFs analysis by incorporating additional interactive elements, distinguishing primary and supporting measures as well as vaguely postulating “minimal confusin”.

Tab. III.2-1 Comparison of existing approaches to measure selection

	Clarity (R.2)	**Vertical integration (R.3)**	**Intersubjectivity (R.4)**	**Interdependencies (R.5)**	**Participation (R.6)**
Giorgini et al. (2008)	No maximum of measures	By goal analysis	Subjective mapping of measures to goals	Isolated consideration	-
Neely et al. (2000)	No maximum of measures	By business strategy	Partial intersubjectivity via checklists	Postulated, but not elaborated	-
Liebetruth and Otto (2006)	Arbitrary maximum of measures	By CSFs	Partial intersubjectivity via optimization model	Postulated, but not elaborated	Assignment of utility scores
Rockart (1982)	No maximum of measures	By CSFs	Subjective mapping of measures to CSFs	Isolated consideration	Explorative interviews
Axson (2007)	No maximum of measures	By CSFs and business strategy	Subjective mapping of measures to CSFs	Isolated consideration	Explorative interviews and “games”

The following findings are noteworthy: Almost all approaches neglect clarity (R.2) as they do not specify how many measures are to be selected. One approach allows to set a maximum number of measures. This is arbitrary and considers neither the decision makers’ information processing capacity nor economic implications. All approaches are vertically integrated by linking measures with CSFs, business strategy, or goals (R.3). Moreover, measure selection is (at least) partially subjective (R.4). Interdependencies among measures are not considered (R.5). Most approaches involve decision makers by means of explorative elements (e. g. interviews or games) (R.6). Summing up, there is a primary research gap with respect to clarity (R.2) and interdependencies (R.5). Furthermore, there still is potential for improvement with respect to intersubjectivity (R.4) and participation (R.6).

We focus on the primary research gap. In the end, this will also ameliorate the other requirements. We adopt the ideas of optimization and preselection of thematically appropriate measures from Liebetruth and Otto (2006), the structuring momentum of CSFs from Rockart (1979), and the idea of explicitly incorporating negative economic implications from Neely et al. (2000). Our contribution is that we formally address the trade-off between provided information, information complexity, and negative economic implications to determine which and how many measures should be selected optimally.

2.3 An optimization model for measure selection

Consider a company where the reporting has historically grown and multiple (data-driven) DSS and data warehouses are in use. In order to react on its decision makers' demand for clear information, the company launches a project for implementing a consolidated DSS. Two essential steps in this project are: (1) structuring the decision makers' IR into relevant fields of action and (2) (pre-) selecting thematically appropriate measures from the existing systems – assuming no new measures will be added. In most cases, it will not be reasonable to integrate all preselected measures – nor even only those desired by the decision makers (e. g. Davis 1982; Ackoff 1967). This is for several reasons: some measures may (partially) "overlap" due to (statistic) interdependencies, decision makers can only cope with restricted information complexity, and customizing as well as maintaining reporting tools is expensive. It is advisable to analyze in advance which fraction of the preselected measures the consolidated DSS should contain. Whereas above thematically appropriate measures had to be (pre-) selected, here measures are of interest that together provide much information about other measures. As indicated, two perspectives are important here: the *economic* and the *informational* perspective. While the former is indispensable when investing in IT, the latter is necessary as DSS primarily aim at supporting decision processes by supplying decision-relevant information (e. g. Power 2002).

In order to determine the optimal fraction of measures, we propose an optimization model. Though being inherently discrete, the problem of measure selection can be interpreted as approx. continuous for sufficiently many measures. This allows to determine algebraic solutions and to gain general insights. We maintain the affiliation with the original problem setting and make reasoning about functions more illustrative by using discrete examples. A basic model for the informational perspective is proposed in section 2.3.1 and extended by the economic perspective in section 2.3.2.

2.3.1 A basic model for the informational perspective

Let us first consider the informational perspective where information has no price. Selecting one of the preselected measures provides information about the measure itself – as it becomes known – and about non-selected measures – due to (statistic) interdependencies. This creates informational utility. The more strongly a measure interdepends with non-selected measures, the more informational utility it creates. This is because a stronger interdependency allows to estimate values more reliably. There are also negative informational effects of selecting measures. Due to increasing information complexity, each additional measure makes it harder to cognitively process the entire amount of information. This creates informational disutility. Thus, there is an *informational trade-off*. The question is: Up to which optimal fraction of measures does the utility due to more information justify the disutility due to higher information complexity? The optimization model relies on the following assumptions:

A.1 There is a given finite set of measures that have been preselected ex ante with respect to thematic appropriateness. Between some measures there are meaningfully interpretable pairwise (statistic) interdependencies, that is, selected measures provide information about (the values of) non-selected measures. All measures together satisfy the decision makers' information requirements and provide complete information. Moreover, all measures together cause highest complexity.

A.2 The fraction of the preselected measures that will be integrated into the consolidated DSS, $x \in [0;1]$, is infinitely divisible (see discussion above). With $x = 0$, no measures are selected. With $x = 1$, all measures are selected.

A.3 $U_{info}(x)$ represents the informational utility due to the information that a fraction of selected measures provides about itself and non-selected measures. $D_{info}(x)$ represents the informational disutility due to information complexity. Both are functions of x and can be forecast ex ante.

On these assumptions, the informationally optimal fraction of measures x^{opt}_{info} can be determined by optimizing the difference between $U_{info}(x)$ with $D_{info}(x)$. This difference is also called informational net utility $U_{info,net}(x)$. The corresponding objective function is given by:

$$U_{info,net}(x) = U_{info}(x) - D_{info}(x) = \max! \qquad \text{(III.2-1)}$$

In order to formalize the optimization model, $U_{info}(x)$ and $D_{info}(x)$ are examined. We start with $U_{info}(x)$. If a (rational) decision maker were restricted to select only one measure, he would select the measure with the highest *individual* informational utility – say m_1 –, i. e. the measure that in sum interdepends most strongly with the non-selected measures. If the decision maker were allowed to select two measures, he would take those that create the highest *joint* informational utility – say m_2 and m_3. In general, this joint informational utility is higher than the individual utility of m_1. This is because either m_1 is kept (as m_2 or m_3) and another measure is added or m_1 is discarded and two other measures with higher joint utility are chosen. The only exception is if all measures interdepend perfectly. In this case already one measure alone – no matter which – provides complete information. In general, the joint informational utility of m_2 and m_3 is smaller than the sum of both individual utility values. This is because interdependencies cause "informational overlap". To put it more precisely: If we only consider m_2 and m_3, the joint utility of knowing both m_2 and m_3 is smaller than the sum of the individual utility values due to knowing m_2 (or m_3) and its interdependency with m_3 (or m_2). If m_2 and m_3 interdepend, m_2 provides information about m_3 – and vice versa. The only exception is if m_2 and m_3 are (statistically) independent of each other. In this case, the joint utility equals the sum of both individual utility values. If we consider all non-selected measures, the joint interdependency-induced utility of m_2 and m_3 is smaller than the sum of the individual interdependency-induced utility values of m_2 and m_3. For each non-selected measure, the strongest interdependency will be used to estimate its value. The only exception is if m_2 and m_3 are independent of all non-selected measures or interdepend with disjoint subsets of non-selected measures. With many measures at hand, this is rather unlikely. Hence, the marginal utility of selecting m_2 and m_3 (two measures) compared to selecting m_1 (one measure) is smaller than (and exceptionally equal to) the marginal utility of selecting m_1 (one measure) compared to selecting zero measures. This holds for any number of measures. Hence, the more measures are selected – i. e. the higher x is –, the higher is the joint informational utility and the less is the marginal utility. In mathematical terms, $U_{info}(x)$ is increasing $(\partial(U_{info}(\mathrm{x}))/\partial x \leq 0)$ and concave $(\partial^2(U_{info}(x))/\partial x^2 \leq 0)$. If we neglect the discussed exceptions and treat $U_{info}(x)$ as *strictly* increasing and concave, it may be formalized in a simplifying manner as follows:

$$U_{info}(x) = x^{\alpha} \cdot A \text{ with } \alpha \in \left]0;1\right] \text{ and } A \in IR^{+} \qquad \text{(III.2-2)}$$

Selecting no measures provides no information ($U_{info}(0) = 0$), whereas – according to A.1 – selecting all measures provides complete information ($U_{info}(1) = A$). The constant A represents the decision makers' present-value monetary equivalent of complete information, that is, the amount of money they are willing to pay at the moment of measure selection for complete information during the planning horizon, i. e. as long as the selected measures are in use. Reasoning from an informational perspective, A represents the value of information by itself. It does not incorporate payments e. g. for data collection. The transformation into monetary units enables to integrate the economic perspective later. The diminishing marginal utility, which was introduced above and is caused by a higher fraction of measures, is formalized by the fact that the exponent α is restricted to]0;1]. This also excludes the case where all measures interdepend perfectly, which would lead to a non-realistic course of $U_{info}(x)$. A value of α close to 0 is appropriate if all preselected measures interdepend rather strongly. Therefore, very few measures already create almost complete information. A value of α close to 1 is appropriate if all measures are rather independent, that is, the marginal utility is rather constant. A mean value of α indicates that the measures split into several groups with strong intra-group and weak inter-group interdependencies. The higher the value of α, the more (and the smaller) groups tend to exist.

The objective function's second component represents the disutility created by information complexity $D_{info}(x)$. It intuitively holds that the more measures are selected, the more complex is it to cognitively process them. Mathematically spoken, $D_{info}(x)$ increases with x. According to cognitive sciences (e. g. Miller 1956; Duncan 1980), the amount of information becomes overproportionally more complex when the fraction of measures increases. Hence, a higher fraction x is also characterized by an increasing marginal disutility with respect to $D_{info}(x)$. In summary, $D_{info}(x)$ is strictly increasing ($\partial(D_{info}(x))/\partial x>0$) and strictly convex ($\partial^2(D_{info}(x))/\partial x^2>0$). This can be formalized as follows:

$$D_{info}(x) = x^{\beta}\cdot B \text{ with } \beta \in\ ]1;\infty[\text{ and } B \in IR^+ \qquad \text{(III.2-3)}$$

Selecting no measures does not lead to complexity ($D_{info}(0) = 0$), whereas – according to A.1 – selecting all measures leads to highest complexity ($D_{info}(1) = B$). The constant B represents the decision makers' present-value monetary equivalent of understanding complete information during the planning horizon. The increasing marginal disutility, which was introduced above and is caused by a higher fraction of measures, is formalized by the fact that the exponent β is restricted to $]1;\infty[$. Its value depends on the decision makers' and employed reporting tools' ability of coping with information complexity[1]. A value close to 1 is appropriate if the decision makers already have serious problems with processing few measures and/or the employed reporting tools are restricted to a few measures. The higher the value of β, the less decision makers are susceptible to information complexity and/or the more powerful are the employed reporting tools. Based on (III.2-1) to (III.2-3), the optimization model is as follows:

$$\text{Maximize} \quad U_{info,net}(x) = U_{info}(x) - D_{info}(x) = x^{\alpha}\cdot A - x^{\beta}\cdot B$$

$$\text{w. r. t. } x \in [0;1] \qquad \text{(III.2-4)}$$

[1] To simplify matters, β is viewed as average value of how well decision makers/reporting tools are able to cope with information complexity. Of course, it can be further refined with respect to different groups/types or even individual decision makers/reporting tools.

A mathematical analysis shows that $U_{info,net}(x)$ strictly increases until $x^{*}_{info} = [(A\cdot\alpha)/(B\cdot\beta)]^{1/(\beta-\alpha)}$. Up to that fraction, each additional measure provides more additional information than it causes additional complexity. Beyond, $U_{info,net}(x)$ strictly decreases. Each additional measure then causes more additional complexity than it provides additional information. As x is restricted to $[0;1]$, the optimal fraction is $x^{opt}_{info} = \min\{x^{*}_{info};1\}$. Due to the concave course of $U_{info,net}(x)$, a border solution such as $x^{opt}_{info} = 1$ only occurs on rare occasions (see below).

Two interesting questions are: How is the decision makers' attitude towards complete information and highest complexity reflected in A and B? How do both parameters ceteris paribus affect the course of $U_{info,net}(x)$ and the position of x^{opt}_{info}? The following case differentiation is also depicted in Fig. III.2-1. If $A = B$, complete information creates as much utility as highest complexity creates disutility. Decision makers then are indifferent between making decisions based on zero measures or based on all preselected measures. The optimal fraction is $x^{opt}_{info} = (\alpha/\beta)^{1/(\beta-\alpha)}$ and only depends on α and β. If $A < B$, complete information creates less utility than highest complexity creates disutility. Decision makers prefer making decisions based on zero measures to making decisions based on all measures. The optimal fraction x^{opt}_{info} is ceteris paribus smaller than in the first case. If $A > B$, complete information creates more utility than highest complexity creates disutility. Decision makers prefer making decisions based on all measures to making decisions based on zero measures. $U_{info,net}(x)$ becomes zero only once in $[0;1]$. The optimal fraction x^{opt}_{info} is ceteris paribus higher than in the first case. For certain constellations of α and β (see Fig. III.2-1 on the right), $U_{info,net}(x)$ could have its maximum x^{*}_{info} outside the interval $[0;1]$. With x being restricted to this interval, the optimal fraction then is $x^{opt}_{info} = 1$. This is the only case where it may be informationally optimal to select all measures.

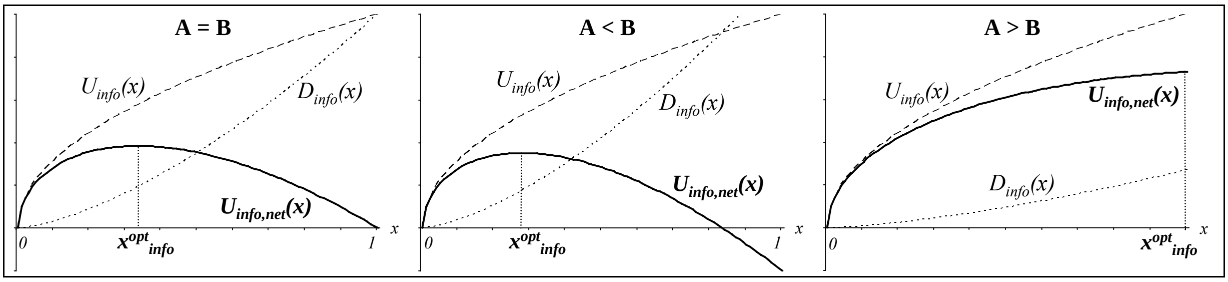

Fig. III.2-1 Exemplary courses of $U_{info}(x)$, $D_{info}(x)$, and $U_{info,net}(x)$

2.3.2 An extended model for the informational and the economic perspective

In reality, information is not for free. Hence, it is necessary to integrate an economic perspective. In order to support decision makers, measures need to be compiled into reporting tools (e. g. management cockpits and dashboards). These need to be customized and maintained during their time in use. Abstracting from fixed costs, this leads to one-time and continuous payments. Both create economic disutility and influence measure selection. Thus, there is a *joint informational and economic trade-off*. The question is: Up to which optimal fraction of measures does the additional informational net utility justify the additional economic disutility due to higher present-value payments for customization and maintenance? The extended model additionally relies on the following assumptions:

A.4 All preselected measures are implemented and their values can be extracted automatically from the respective application systems. The consolidated DSS will be connected to the existing application systems.

A.5 $D_{econ}(x)$ is the economic disutility due to the present-value payments for customizing and maintaining reporting tools. It is a function of x and can be forecast ex ante.

On the assumptions A.1 to A.5, the informationally *and* economically optimal fraction $x^{opt}_{info+econ}$ can be determined by optimizing the difference between $U_{info,net}(x)$ and $D_{econ}(x)$. This difference is also called joint informational and economic net utility $U_{info+econ,net}(x)$. The objective function is given by:

$$U_{info+econ,net}(x) = U_{info,net}(x) - D_{econ}(x) = U_{info}(x) - D_{info}(x) - D_{econ}(x) = \max! \qquad \text{(III.2-5)}$$

To formulate the extended optimization model, $D_{econ}(x)$ is examined. According to A.4, payments for systems integration and data collection need not be considered. The more measures are selected, the more time consuming – and expensive – is it to initially customize reporting tools. Imagine the selected measures had to be integrated into a dashboard. If only one measure is selected, the dashboard can be customized easily. If two measures are selected, an overall layout is more difficult (but still easy) to find. The more measures are selected, the overproportionally more time-consuming – and expensive – is it to find an adequate overall layout. This includes choosing among different visualization elements, adapting their size, trying different layouts, or – in the worst case – changing the reporting tool. This also applies to the present-value payments for maintaining reporting tools. These arise e. g. from updating ETL procedures, assuring data quality, or changing selected measures. According to Axson (2007), in average 15 to 20 % of the selected measures will have to be changed during the first year, 10 to 15 % in the following years. Hence, the more measures are selected – that is, the higher x is –, the higher is the economic disutility and the higher is the marginal disutility. Mathematically spoken, $D_{econ}(x)$ is strictly increasing ($\partial(D_{econ}(x))/\partial x>0$) and strictly convex ($\partial^2(D_{econ}(x))/\partial x^2>0$). This may be formalized as follows:

$$D_{econ}(x) = x^{\gamma}\cdot C \text{ with } \gamma \in\ ]1;\infty[\text{ and } C \in IR^{+} \qquad \text{(III.2-6)}$$

Selecting no measures does not lead to payments ($D_{econ}(0) = 0$), whereas selecting all measures leads to highest payments ($D_{econ}(1) = C$). The constant C represents the highest amount of present-value payments due to customization and maintenance of reporting tools. The increasing marginal disutility, which was introduced above and is caused by a higher fraction of measures, is formalized by the fact that the exponent γ is restricted to $]1;\infty[$. A value close to 1 is appropriate if a small fraction of measures already leads to high payments and each measure causes approx. the same marginal disutility. The higher γ is, the less payments and marginal disutility causes a small fraction of measures and the higher is the marginal disutility of higher fractions. Based on (III.2-4) to (III.2-6), the extended optimization model is as follows:

$$\text{Maximize} \quad U_{info+econ,net}(x) = U_{info}(x) - D_{info}(x) - D_{econ}(x) = x^{\alpha}\cdot A - x^{\beta}\cdot B - x^{\gamma}\cdot C$$

$$\text{w. r. t. } x \in [0;1] \qquad \text{(III.2-7)}$$

Although there is no general algebraic solution, the course of $U_{info+econ,net}(x)$ and the position of $x^{opt}_{info+econ}$ can be discussed with respect to the component functions (see Fig. III.2). As $U_{info,net}(x)$ is concave and $D_{econ}(x)$ is convex, $U_{info+econ,net}(x)$ is concave with one global maximum at $x^{*}_{info+econ}$. As $U_{info+econ,net}(x)$ equals $U_{info,net}(x)$ diminished by $D_{econ}(x)$, the joint informational and economic optimum $x^{opt}_{info+econ}$ is smaller than or equal to x^{opt}_{info}, that is, $x^{opt}_{info+econ} \in\ ]0;x^{opt}_{info}]$. This is reasonable because x^{opt}_{info} is determined on the assumption that information has no price. If $D_{econ}(x)$ is close to zero – e. g. for large γ and/or very small C –, measures can be selected almost negligent of negative economic effects. Then $x^{opt}_{info+econ}$ and x^{opt}_{info} are approx. equal. If $D_{info}(x)$ is close to zero – e. g. for large β and/or very small B –, decision makers are hardly susceptible to information complexity and/or powerful reporting tools are employed. Then an approx. solution is $x^{opt}_{info+econ} \approx (A\cdot\alpha/C\cdot\gamma)^{1/(\gamma-\alpha)}$. In this case, analogous to above, the relationship between the decision makers' subjective attitude towards complete information and highest (present-value) payments can be analyzed with respect to A and C.

Concluding, the optimization model allows determining the optimal fraction of measures to be chosen from a preselected set of thematically appropriate measures. Accordingly, those measures are selected that together create the highest informational utility. The model integrates an informational and an economic perspective. The former reflects the decision makers' attitude towards information and information complexity. The latter considers present-value payments for customizing and maintaining reporting tools. It could be shown that, in general, the selection policies of all-or-none or the-more-the-better, which are often implemented in business practice, are reasonable neither from an informational nor from a joint informational and economic perspective. What makes sense instead is a differentiated and balanced selection of measures.

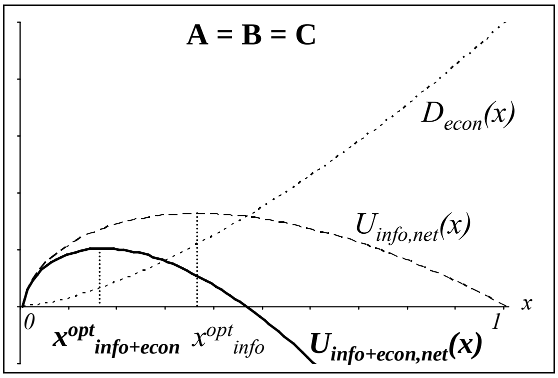

Fig. III.2-2 Exemplary course of $U_{info+econ,net}(x)$ for A = B = C

2.4 Evaluation

2.4.1 Applying the optimization model in business practice

The optimization model was developed in the context of a project at the German business-to-business sales organization of a global electronics and electrical engineering company. As there were only few measures, the model could be applied in a *discretized* form. If there had been very much measures, we would have had to evaluate a manageable subset in order to infer the continuous functions introduced above. Due to confidentiality, all data is anonymized and modified. Yet the principal results still hold. The project's overall goals were to better support the sales force, to reduce IT operation costs, and to modernize sales reporting. As for the first two goals, the company decided to introduce a single CRM system and to harmonize the application landscape, which consisted of more than one hundred division-specific legacy systems. The reporting mainly consisted of financial and lagging measures such as volume of sales and price margin. It was to be modernized with respect to *non-monetary* and *leading* measures. Our task was to structure the salespeople's IR into CSFs and to select appropriate measures. At first, candidate CSFs were identified by explorative interviews with sales managers and senior members of the CRM board. Sales managers had usually worked as sales representatives for several years and were supposed to provide valuable hints with respect to IR and sales reporting. They were selected by reputational methods (Knoke 1993). For each candidate CSF, several items were identified and compiled into a five-point Likert scale-based questionnaire. After a pretest, the questionnaire was presented to 25 sales managers (the amount was restricted by the project budget). All in all, CSFs were identified for 3 perspectives, namely organizational structures and processes (e. g. long-term customer care, cross-divisional cooperation), salespeople's skills and knowledge (e. g. with respect to installed base and competitors' portfolios), and IT functionality (e. g. integration with office communication software, IT-based planning of sales calls).

The CSF "cross-divisional cooperation" will serve as example. Together with the sales managers, we retrieved 8 thematically appropriate measures. These were: fraction of converted leads[2] from other divisions (*%_leads*), average overall time spent on creating leads for other divisions (*∅_T_leads*), average time spent on creating one lead (*∅_T_lead*), number of trainings on other divisions' portfolios (*#_trainings*), number of meetings with colleagues from other divisions (*#_meetings*), number of sales calls with colleagues from other divisions (*#_calls*), number of shared customers (*#_customers*), number of bids for customers of other divisions (*#_bids*). All measures had existed for several years and were reported monthly on a sales manager's granularity.

First, we assessed informational utility $U_{info}(x)$. The exponent α – which indicates how the measures interdepend – was operationalized based on Pearson's correlation coefficient. That is, we treated the interdependencies as pairwise, symmetric, and linear. We accepted this simplification because the correlation coefficient is an intuitive, widely used, and relatively easy-to-compute measure. Moreover, linear interdependencies are often considered as sufficiently good approximations for many economic settings (Edwards 1976). This turned out to be useful because, due to missing hierarchical and logic structures, the existence and strength of interdependencies among non-monetary and leading measures often need to be assessed empirically e. g. by interviewing domain experts and analyzing historical data (Küpper 2005). Let $M = \{m_1, m_2, ..., m_n\}$ comprise n preselected and thematically appropriate (metrically scaled) measures between some of which there are meaningfully interpretable interdependencies/correlations. We considered absolute values

[2] In the CRM context, a lead represents a hint with low degree of maturity from inside or outside one's division that refers to a potential customer or project opportunity.

as the correlation coefficient's algebraic sign only indicates direction, not strength. The values are represented as $n{\times}n$-matrix C_M where c_{ij} indicates how strong m_i and m_j correlate and where $c_{ij} = 0$ if m_i and m_j are statistically independent or if their interdependency/correlation cannot be meaningfully interpreted ($0 \leq i, j \leq n, i \neq j$). The individual correlations of a measure m_i equal the i-th column vector of C_M.

$$c_i = (c_{i1}, c_{i2}, \ldots, c_{in})^{\mathrm{T}} \tag{III.2-8}$$

The joint correlations of multiple selected measures $m_1,\ldots,m_i$ (without loss of generality) are also represented as vector $c_{1,\ldots,i}$. The elements of all selected measures are 1 (perfect autocorrelation). The element of each non-selected measure indicates the strongest correlation with any measure selected so far. This is reasonable because if decision makers want to estimate the value of a non-selected measure m_j, they will reasonably revert to the selected measure that correlates most strongly with m_j.

$$c_{1,\ldots,i} = (\max\{c_{11},\ldots,c_{i1}\}, \max\{c_{12},\ldots,c_{i2}\}, \ldots, \max\{c_{1n}, \ldots,c_{in}\})^{\mathrm{T}} \tag{III.2-9}$$

The concept of joint correlations enables to formalize a discretized informational utility as function of x. We need the highest joint correlation of $x{\cdot}n$ measures. It is determined by calculating the highest scalar product value $\langle 1,c^x \rangle$ where 1 is an n-vector $(1, 1, \ldots, 1)^{\mathrm{T}}$ and c^x is the joint correlations vector of $x{\cdot}n$ arbitrary measures. Dividing the scalar by n normalizes it to [0;1]. This operationalization can be interpreted as a monetized mean absolute correlation.

$$U_{info}(x) = [\max \{ \langle 1,c^x \rangle \mid x{\cdot}n \text{ measures are selected} \} / n] \cdot A \tag{III.2-10}$$

Tab. III.2-2 Absolute correlation coefficient values of the preselected measures

	%_leads	Ø_T_leads	Ø_T_lead	#_trainings	#_meetings	#_calls	#_customers	#_bids
%_leads	1.00	0.43	0.83	0.67	0.00	0.42	0.34	0.96
Ø_T_leads	0.43	1.00	0.34	0.00	0.00	0.00	0.12	0.54
Ø_T_lead	0.83	0.34	1.00	0.67	0.00	0.00	0.36	0.24
#_trainings	0.67	0.00	0.67	1.00	0.00	0.25	0.41	0.21
#_meetings	0.00	0.00	0.00	0.00	1.00	0.38	0.25	0.12
#_calls	0.42	0.00	0.00	0.25	0.38	1.00	0.74	0.73
#_customers	0.34	0.12	0.36	0.41	0.25	0.74	1.00	0.58
#_bids	0.96	0.54	0.24	0.21	0.12	0.73	0.58	1.00

After CSF analysis, some sales managers from the CRM board were asked to (subjectively) judge which interdependencies between measures are meaningfully interpretable as regards the sales domain. The strength of these interdependencies was calculated by means of absolute correlation values based on historical data. Tab. III.2- shows the results with the light grey cells marking excluded interdependencies/correlations. Concerning the value of A – which represents the sales managers' present-value monetary equivalent of complete information – we asked each sales manager how many daily rates he would pay for having complete information on cross-divisional cooperation during the planning horizon. We obtained an average of 10 daily rates, which we multiplied with the sales managers' average daily rate of 750 € and their overall number – there were 50. We finally obtained A = 375,000 €. As for informational disutility $D_{info}(x)$, the sales managers received sample reports. Each contained a different amount of measures, but had exactly the same layout as the reports that were planned to be finally used. The sales managers' task was to entirely understand the reports. For each amount of measures, we logged the time. In order to determine the value of B, we used the average value for 8 measures – which was 2.0 hours. We normalized it with respect to the sales managers' average daily working time – which was 9 hours. Then, we multiplied it with the sales managers' average daily rate and their overall number. As the report was planned to be presented monthly and the planning horizon was 3 years, we calculated the annual payments and the corresponding present value with an interest rate of 10 %. Assuming that the managers had to try to understand the report completely anew each time they received it, we obtained $B = 273{,}554$ €. We used the other time values for approximating β. The sales managers coped well with a low number of measures, but had problems with more than approx. 4–5 measures. So we obtained $\beta = 2.8$. The economic disutility $D_{econ}(x)$ was calculated based on Boehm's widespread cost estimation model CoCoMo (1981). Together with the company's DSS experts, we parameterized the estimation model as $PM{=}2.94{\cdot}0.20{\cdot}LOC^{1.2}$ where PM and LOC denote person months and thousand lines of code respectively. The present-value effort for customizing a report with one measure and maintaining it during the planning horizon was estimated equivalent to 1.250 LOCs. With the DSS experts' average daily rate of 400 € and 20 working days per month, we obtained $C = 74{,}553$ € and $\gamma = 1.2$.

Tab. III.2-3 (Dis-) Utility values for the CSF "cross-divisional cooperation"

No. of selected measures	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fraction *x*	0	0.125	0.25	0.375	0.5	0.625	0.75	0.875	1
$U_{info}(x)$ [€]	0	217,969	281,719	310,781	337,500	352,969	365,156	373,125	375,000
$D_{info}(x)$ [€]	0	810	5,640	17,552	39,279	73,368	122,240	188,220	273,554
$U_{info,net}(x)$ [€]	0	217,159	276,079	293,229	**298,221**	279,601	242,916	184,905	101,446
$D_{econ}(x)$ [€]	0	6,148	14,125	22,978	32,451	42,415	52,789	63,515	74,553
$U_{info+econ,net}(x)$ [€]	0	211,011	261,954	**270,251**	265,770	237,185	190,127	121,390	26,893

On this basis, we determined the optimal fraction of measures $x^{opt}_{info+econ}$ by computing the joint informational and economic net utility $U_{info+econ,net}(x)$ (see Tab. III.2- and Fig. III.2). If we had only considered the informational perspective, the highest informational net utility would have resulted from $x^{opt}_{info} = 0.5$. We would have selected the 4 measures with the highest informational utility, i. e. *%_leads, Ø_T_leads*, *#_meetings*, and *#_customers*. As we also took on an economic perspective, the highest joint net utility resulted from $x^{opt}_{info+econ} = 0.375$. We selected the 3 measures with the highest informational utility, i. e. *%_leads*, *#_customers*, and *#_bids*. Here, it becomes obvious that measures can be discarded if the number of selected measures changes.

We applied the same procedure to the other CSFs. Advantageously, this caused considerably less effort because $D_{info}(x)$ and $D_{econ}(x)$ needed not to be determined anew. $U_{info}(x)$ could be calculated based on historical data so that the sales managers' expertise was only required for preselecting thematically appropriate measures and identifying meaningfully interpretable interdependencies. In sum, we modernized the company's sales reporting by identifying CSFs, by integrating non-monetary and leading measures, and by significantly reducing the overall number of measures.

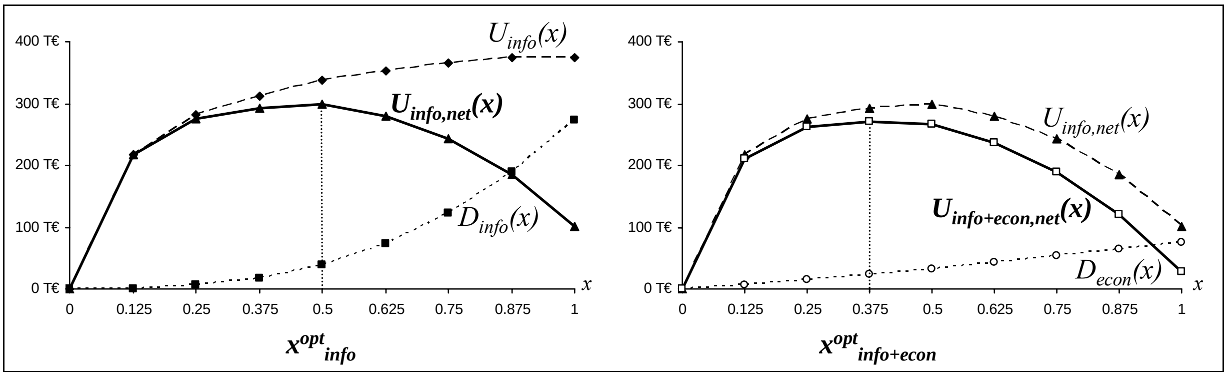

Fig. III.2-3 Visualization of the (dis-) utility values for the CSF "cross-divisional cooperation"

2.4.2 Checking the optimization model against the PMS requirements

The optimization model particularly aims at closing the primary research gap with respect to clarity (R.2) and interdependencies (R.5) (see section 2.2). By requiring to select a manageable amount of measures, the model addresses clarity in an explicit manner. Informational disutility expresses the decision makers' and reporting tools' ability of coping with informational complexity and is contrasted to informational utility. Thereby, we make sure that the whole amount of information does not become too complex and remains manageable for the decision makers. Interdependencies are also addressed explicitly. This is because informational utility uses interdependencies in order to express how "much" information measures provide about one another. The example showed – albeit in a simplifying manner – how an interdependency-based informational utility can be operationalized for non-monetary and leading measures with Pearson's correlation coefficient. Moreover, the model makes the process of measure selection more inter-subjectively comprehensible (R.4). Although most parameters cannot be determined without subjective influences, just the fact that it is clear how they are formally linked increases intersubjectivity. Decision makers do not only participate by means of explorative interviews, but also in a structured manner by validating interdependencies and estimating model parameters (R.6). Concluding, the model does not only address the primary research gap, but also ameliorates the other PMS requirements.

2.5 Summary and future research

An optimization model has been proposed that helps to determine which and how many measures should be selected from a set of thematically appropriate measures in order to monitor specific fields of action. Informational and economic objectives are considered. That is (statistic) interdependencies among measures, decision makers' and reporting tools' ability of coping with information complexity as well as payments for customizing and maintaining reporting tools influence measure selection. The model's principle applicability was shown with a real-world example. Admittedly, business practice entails problems (e. g. estimation of costs, data collection in complex social contexts, decision makers' partial inability of unambiguously specifying IR) that make it hard to achieve truly optimal solutions. In order to cope with some of these problems, it may be useful for companies to implement the model stepwise and to involve operating staff in data collection. Nevertheless, the proposed model is a first step towards a more well-founded measure selection. It will be subject to future research:

1. The optimization model is applied to one field of action a time. Several fields of action can only be addressed successively and isolated. The fact that measures may be thematically appropriate for more than one field of action is not considered. Hence, an integrated perspective is desirable and should be added.

2. So far, only measures from existing application systems are considered. On the one hand, this is reasonable as in many companies more measures exist than any decision maker can ever analyze. On the other hand, positive effects of innovative measures are neglected and need to be integrated.

3. (Data-driven) DSS and data warehouses do not only comprise measures, but also other master data for evaluation. In order to deal with their full scope, the model needs to be complemented e. g. by an approach which assesses relevant dimensions and dimension elements.

4. Although the model has been employed successfully with real-world data, empirical evidence is missing with respect to whether its recommendations actually improve decision quality. It would be insightful and strengthen evaluation to conduct respective empirical studies.

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IV Anforderungsanalyse für operative Systeme – am Beispiel von CRM-Systemen (Beitrag: „A multi-perspective analysis of operational critical success factors for customer relationship management – A descriptive case study")

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Erschienen in:	Proceedings of the 15th Americas Conference on Information Systems, San Francisco
Hinweis:	Die hier abgedruckte Fassung ist eine Erweiterung des Konferenzbeitrags.

Abstract:

Despite much IS research on customer relationship management (CRM) in general and respective critical success factors (CSFs) in particular, CRM projects are still subject to failure rates of up to 75 %. One reason may be that most studies focus on a technological or project perspective while neglecting the process and organizational perspectives. On the one hand, this constrains a holistic implementation of CRM such as postulated in literature. On the other hand, existing CSFs such as "management support", "design for flexibility", or "board awareness of strategic potential of IT" are rather abstract and biased towards CRM build-time, i. e. the project phase. Both properties diminish the CSFs' value for IS practitioners. Against this background, there is a research need for *concrete and run-time CSFs – which will be called operational CSFs – to be investigated from an organizational and process perspective. In order to attain preliminary in-depth knowledge of this contemporary and so far relatively unstructured phenomenon within its real-life context, we conducted a descriptive single-case study within the German sales department of a global company from the electronics and electrical engineering industry. In the course of a two-stage data collection and analysis process, 56 sales managers were interviewed in semi-structured and questionnaire-based settings with respect to three perspectives, namely organizational setting, CRM process, and information requirements. While the first two perspectives directly address the research need sketched above, the third was integrated to elicit concrete hints regarding the design and customization of CRM systems. Our contribution to existing knowledge consists in rankings of operational CSFs for each perspective. These rankings are enriched by qualitative in-depth information. Since we had the opportunity to study the company's two top-selling so-called sales business types (SBTs) "product sales" and "solution sales", we also discuss differences and commonalities with respect to operational CRM-related CSFs.*

1 Introduction

After many years of enthusiasm, customer relationship management (CRM) – which may be basically defined as a strategic and IT-based approach with the objective of creating improved shareholder value via profitable and long-term customer relationships (Payne and Frow 2005; e. g. Goodhue et al. 2002) – faces an ambivalent discussion. The reason is that CRM projects can achieve high return on investment, but also suffer from high failure rates. An indication for the former may be the fact that the worldwide CRM software market is expected to grow by an average annual rate of 10 % up to $13.3 billion in 2012 (Mertz 2008). Moreover, companies still spend large amounts of money on CRM projects – typically $2 million to $5 million per deployment (Fox 2009). Although these figures may have been compiled before the global economic crisis, their principal tendency is certainly still valid to a diminished degree. Companies would not invest such high amounts of money if they expected low or no returns. This contrasts sharply with the reported failure rates of up to 75 % (Langerak and Verhoef 2003; Reinartz et al. 2004) – which of course should be subject to critical analysis (for an overview see e. g. Zablah et al. 2004). In order to reduce these failure rates, much IS research has been conducted with respect to CRM-related critical success factors (CSFs). CSFs are the few fields of action where satisfactory results drive competitive performance (Rockart 1979).

Interestingly, most current studies about CRM-related CSFs focus on a technological or project perspective while rather neglecting an organizational or process perspective (see next section). This situation bears several drawbacks: First, studies that reduce CRM to technological issues ignore that this is known to be a key reason of failure (Kale 2004; Richard et al. 2007) – although IT is a CRM enabler (Dibb 2001; Kim and Mukhopadhyay 2006). Second, neglecting the organizational and process perspective constrains a holistic implementation of CRM such as postulated e. g. by Payne and Frow (2005). Third, the CSFs identified so far are biased towards CRM build-time, i. e. the project phase. CSFs concerning CRM run-time, i. e. CRM operations, are investigated insufficiently. This becomes even more surprising if one considers that run-time generally exceeds build-time and that run-time CSFs should already be considered during build-time in order to set the course for run-time CRM success at an early stage. Fourth, many CSFs are rather abstract. Some examples are “management support”, “design for flexibility”, or “board awareness of strategic potential of IT”. Indeed, this makes the CSFs applicable to different settings, but hardly provides concrete help for IS practitioners. In a nutshell, there is an abundance of rather abstract build-time CSFs and a research need for concrete run-time CSFs to be analyzed particularly from an organizational and process perspective. We will refer to concrete run-time CSFs as *operational CRM-related CSFs* throughout this paper.

In this paper, we analyze operational CSFs of sales departments, which play a key role in CRM apart from marketing and service departments. We further sharpen the focus in three ways: First, we concentrate on sales departments that serve business customers by area-covering direct sales. This is worth studying because such departments usually combine high workforce, complex interaction among sales representatives, back office, and other departments, a differentiated portfolio of products and services, a multi-level management hierarchy, and high demands of CRM systems. Second, there is a focus on a sales representative's point of view. The reason is that in sales departments such as just mentioned it is the sales representatives who have the highest fraction of customer contact. Third, we take on three perspectives: organizational setting, CRM process, and information requirements. While the first two address the research need presented above, the third perspective is supposed to provide concrete hints for the design and customization of CRM systems. Thus, our research question is: *What are the operational CRM-related CSFs for sales representatives working in sales departments that serve business customers by area-covering direct sales with respect to organizational setting, CRM process, and information requirements?*

In order to approach this question, we conducted a descriptive single-case study. This seemed appropriate because we intended to investigate a contemporary and so far relatively unstructured phenomenon within its real-life context where actual behavior could not be controlled and the knowledge base is poor (Yin 2009). Moreover, case studies have already been used to study both CRM (Goodhue et al. 2002; e. g. Abbott et al. 2001) and CSFs (e. g. Bull 2003; Poon and Wagner 2001). In addition, they are a generally acknowledged IS research method (Benbasat et al. 1987; Lee 1989; Darke et al. 1998; Schubert and Wölfle 2007). The case study's philosophical grounding is interpretivist (Walsham 1995). The research question qualifies sales departments as unit of analysis. Against this background, we selected the German sales department of a globally acting company from the electronics and electrical engineering industry. This was because we estimated it to be a typical case and we had access to data in the context of a public-private cooperation project. Moreover, we had the opportunity to investigate the company's two top-selling sales business types (SBTs), namely "product sales" and "solution sales", which will be defined below. Due to confidentiality, the company's identity must not be disclosed. Consistent with its descriptive nature, this case study does not intend to test or extend existing theory. Its contribution to theory development consists in providing preliminary in-depth knowledge as stimulus for inductive theory-building.

The paper is structured as follows: In order to substantiate the research need, the next section compiles the state of the art regarding CRM-related CSFs. After that, we report the case study context according to Dubé and Paré (2003) as well as the data collection and analysis process. We then present the identified operational CSFs, rankings for each perspective and SBT as well as a brief synopsis. In the last section, we summarize the findings, discuss limitations, and point out managerial as well as theoretical implications.

2 State of the art concerning CRM-related critical success factors

Many researchers have already dealt with CRM-related CSFs. We structure the findings of multiple papers by means of the conceptual framework proposed by Kim et al. (2002). The papers were selected for two reasons: First, they deal with factors influencing CRM success/failure. Second, most of them were published recently in international journals and proceedings and are supposed to represent the current mainstream of expansive literature on CRM-related CSFs to a large extent. Current trends such as electronic or social CRM (Lin et al. 2006; e. g. Hayes Weier 2009) as well as general success factors for introducing enterprise systems (e. g. Sumner 1999) were not considered. As with any attempt to organize past research, a certain degree of arbitrariness occurs (DeLone and McLean 1992). In some cases, it was difficult to unambiguously assign the existing CSFs to one perspective. Moreover, similar CSFs were given different names so that a careful consolidation and grouping had to be conducted. It may also be questioned whether the framework is too straight-forward and/or whether its perspectives are sound and complete. Nevertheless, we assume that the framework and the assignment of existing CRM-related CSFs to perspectives provide basic assistance with substantiating the research need. Focusing on our case study’s context, process, and findings below, we summarize the existing CSFs in Tab. IV-1. Zablah (2004) compiled a similar, but less comprehensive and structured overview. Kim et al. (2002) presented a brief overview focusing on (e)CRM systems. The findings of both papers have been integrated as far as possible and reasonable.

Tab. IV-1 Conceptual framework of CRM-related CSFs

Organizational CSFs	Process CSFs	Technological CSFs	Project CSFs

CRM ownership at corporate level / Appointment of Chief Customer Office / Organization-wide commitment (Bohling et al. 2006; Xu et al. 2002; Ryals and Knox 2001) Knowledge management capabilities (Croteau and Li 2003) Customer-centric organization / Focus on customer needs (Langerak and Verhoef 2003; Xu et al. 2002; Ryals and Knox 2001; Wilson et al. 2002; Bose 2002; Rigby et al. 2002; Payne and Frow 2006; Ryals and Payne 2001; Sheth and Sisodia 2001) Solid training program (Bose 2002)	Approval procedures allowing for uncertainty (Wilson et al. 2002) Identification of customer/decision interaction points (Bose 2002) Delivery of customized service over all channels (Xu et al. 2002)	User involvement during system design (Kim et al. 2002; Xu et al. 2002; Wilson et al. 2002) Design for flexibility / scalability (Xu et al. 2002; Wilson et al. 2002) Provision of all necessary customer information / Customer data redesign (Xu et al. 2002; Bose 2002) Continuous evaluation (Bull 2003; Bose 2002; Payne and Frow 2006) Board awareness of strategic potential of IT (Wilson et al. 2002) Effective sourcing strategy (Bull 2003; Kim et al. 2002) Implementation of central data warehouse and analytic functionality (Xu et al. 2002) Integration of front-end and back-end systems / Cross-functional integration (Xu et al. 2002; Ryals and Knox 2001; Wilson et al. 2002; Massey et al. 2001) Specification of customer data ownership (Ryals and Payne 2001; Massey et al. 2001)	Top management support (Langerak and Verhoef 2003; Bull 2003; Bohling et al. 2006; Ryals and Knox 2001; Croteau and Li 2003; Wilson et al. 2002; Bose 2002; Ryals and Payne 2001; Yu 2001) Adequate financial commitment (Ryals and Payne 2001; Yu 2001) Effective targeting strategy / Quick delivery of business benefits (Goodhue et al. 2002; Bull 2003; Xu et al. 2002; Ryals and Knox 2001; Ryals and Payne 2001; Sheth and Sisodia 2001; Winer 2001; Davids 1999; Shoemaker 2001) Alignment of CRM and business strategy / with IT strategy / with key stakeholders (Langerak and Verhoef 2003; Bohling et al. 2006; Xu et al. 2002; Rigby et al. 2002) Long-term perspective / Staging project / Holistic approach (Goodhue et al. 2002; Langerak and Verhoef 2003; Ryals and Knox 2001; Wilson et al. 2002; Bose 2002; Rigby et al. 2002) Realistic expectations / Feasibility study (Langerak and Verhoef 2003; Bose 2002; Payne and Frow 2006) Integration of external expertise / Project team skills

			(Kim et al. 2002; Bose 2002; Payne and Frow 2006; Ryals and Payne 2001; Shoemaker 2001)

As already mentioned, the following is noteworthy: Most current studies have elicited project or technological CSFs, while rather neglecting the organizational and process perspectives. The drawbacks were already discussed above. Based on Table 1, it becomes clear that even the few existing organizational and process CSFs are rather abstract and address CRM run-time only partially. For instance, it is not clear what CSFs such as “knowledge management capabilities”, “customer-centric organization”, or “approval procedures allowing for uncertainty” concretely mean. Indeed, these CSFs as results of past research may help scholars striving for knowledge at a high theoretical level. For IS practitioners, however, they matter to a restricted degree only. This affirms the research need for more concrete and run-time CRM-related CSFs. As contribution, this case study provides preliminary in-depth insights into operational CRM-related CSFs with respect to the perspectives organizational setting, CRM process, and information requirements.

3 The case study context

The case study was conducted in 2007 within a globally acting company of the electronics and electrical engineering industry. The company mainly addresses business customers via direct sales. Roughly speaking, the company consists of a global headquarters and multiple sales departments. The headquarters split into eight divisions each of which has a different portfolio of products and services. The headquarters is further responsible for corporate functions such as research & development, production, project execution, accounting, and marketing. The sales departments address local markets – mainly countries – by area-covering sales and have a matrix organization. The first dimension comprises sales regions which divide local markets geographically. The second dimension includes the divisions from the headquarters. Fig. IV-1 (a) illustrates this organizational macrostructure. Complementarily, Fig. IV-1 (b) shows the corresponding shell model-like reporting line of a sales department and the corresponding hierarchy levels. This will be helpful during interviewee selection (see next section).

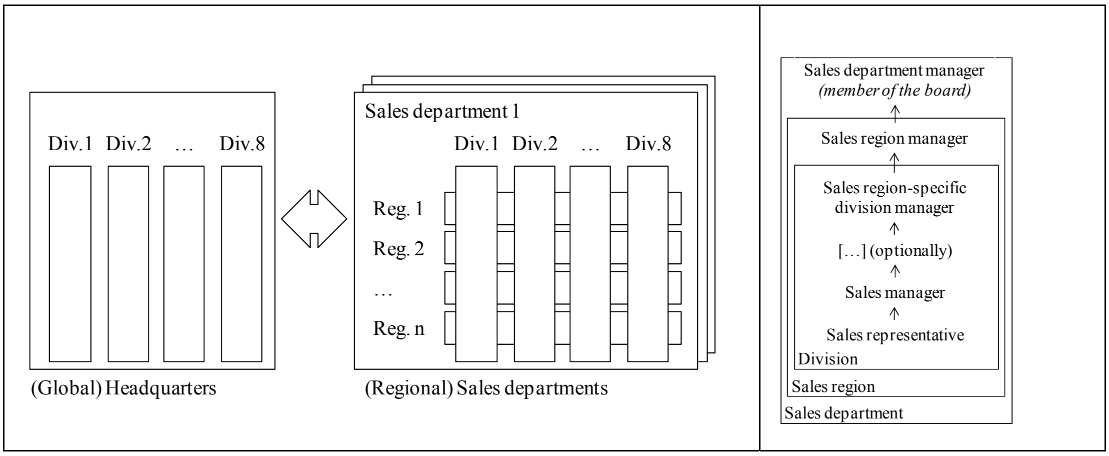

Fig. IV-1 (a) Organizational macrostructure of the case company,
(b) Reporting line of a sales department and corresponding hierarchy levels

Our research group – consisting of four researchers – was part of a CRM project in the sales department responsible for the German market. The project’s objective was to implement a holistic CRM. This meant to redesign the organizational setting and the CRM processes. Moreover, the CRM application landscape of more than 100 legacy systems had to be consolidated. In the end, there should be a CRM system customized to the sales representatives’ information requirements. Sophisticated analytical or collaborative functionality was not considered. Our task was to identify and prioritize operational CRM-related CSFs to facilitate redesign. In order to preserve some distance in the sense of an outside observer (Walsham 1995) – as far as this is possible in such a complex social setting –, we had only little interaction with the members of the operational project groups.

Knowing that CSFs can change over time and intending to identify topical CSFs (Williams and Ramaprasad 1996), the period under investigation was limited to the preceding and the current year, i. e. 2006 and 2007. Data was collected once by indirect observation, i. e. semi-structured and questionnaire-based interviews. We stayed approximately 10 months at the project site, which was necessary to prepare, organize, and conduct all interviews and review rounds. Moreover, we spent only 2 – 3 days a week at the project site. During this period, we obtained help from experienced and sometimes informant-like contact persons such as the project manager and the CRM process board – which consisted of senior sales managers from each division and sales region. Thus, we were able to develop an intimate understanding of the setting and the phenomenon of interest. This was supported by access to complementary sources of evidence such as organization diagrams and process documentations.

We analyzed the company's two top-selling SBTs, namely "product sales" and "solution sales". An SBT represented a homogeneous and unique way of conducting sales with respect to which organizational setting is available, which CRM process actions are particularly important, and which information requirements sales representatives have. SBTs are orthogonal to divisions, i. e. each division has sales representatives for "product sales" and others for "solution sales". The SBT "product sales" refers to the sale of standard products. On rare occasions, this includes delivery, installation, or configuration services. The SBT "solution sales" refers to the combination of standard or individually manufactured products into complex facilities. This implies considerable solution-specific consulting, engineering, assembly, and installation services as well as project management. Both SBTs have in common that sales representatives directly care for customers. They differ in that "product sales" is quite steady with respect to incoming order volume, while "solution sales" is more volatile. Apart from "product sales" and "solution sales", there were further SBTs. They were not analyzed because "product sales" and "solution sales" generated approximately 72 % of the company's incoming order volume in fiscal year 2005/2006 – which was the most topical information available – and there was a corresponding project-wide priority on these two SBTs.

4 Data collection and analysis

We conducted a two-stage data collection and analysis process. Stage 1 aimed at identifying operational CSFs for each perspective under investigation. Stage 2 aimed at assessing the identified CSFs' degree of implementation and at compiling corresponding rankings with respect to each SBT. These rankings may serve as preliminary indications on how “important” a CSF is for an SBT. Please note that stage 2 is not an evaluation and thus compatible with the case study’s descriptive nature. In the entire process, we used multiple quantitative and qualitative sources of evidence, which were compiled into a case study database. The key facts are summarized in Tab. IV-2.

Tab. IV-2 Key facts of the data collection and analysis process

	Stage 1: Identifying operational CSFs	**Stage 2: Compiling CSF rankings**
Sources	Semi-structured interviews (each 2 – 3 hours, attended by 2 researchers) Process documentations, organization diagrams CRM- and sales-related textbooks / scientific papers	Questionnaire-based interviews (each 2 – 3 hours, attended by 1 researcher)
Sample	19 sales managers (across both SBTs)	37 sales managers (16 for “product sales”, 21 for “solution sales”)
Results	Operational CSFs: 8 for “organizational setting”, 6 for “CRM process”, 10 for “information requirements” Additional qualitative information	Rankings for each SBT and cross-SBT analysis from closed-ended items Additional qualitative information from open-ended items

4.1 Stage 1: Identifying operational CSFs

In this stage, semi-structured interviews were conducted. This is because such interviews constitute the foundation of Rockart’s original CSF method (Bullen and Rockart 1981) and are the most important data gathering tool in qualitative IS research (Myers and Newman 2007).

Intending to identify operational CSFs from a sales representative’s point of view, sales managers – the lowest sales management hierarchy level (see Figure 1 (b)) – were interviewed. This seemed appropriate because sales managers had usually gained experience as sales representatives for many years. They were supposed to be able to take on an individual sales representative’s point of view and to integrate the needs of their group’s sales representatives. In order to cover each division and SBT at least once, 19 sales managers were interviewed on the project manager’s recommendation. All these sales managers came from the sales region where the project’s headquarters were.

Concerning interview preparation, the divisions’ CRM processes were analyzed. On the most aggregated level, these processes consistently consisted of three actions, namely “Understand”, “Sell”, and “Care”. This sequence served as consistent line of inquiry during the interviews because it was familiar to each sales manager. Additionally, CRM- and sales-related textbooks as well as scientific papers were analyzed. The objective was twofold: On the one hand, we strived for identifying existing knowledge about CRM-related CSFs in general. On the other hand, we aimed at getting familiar with technical terms and abbreviations. Based on these foundations, we prepared an interview guide with an introduction, instructions, and examples.

The interviews had three sections: introduction, identification of CSFs, and residual questions. The sales managers were asked to comment on what were their challenges, achievements, potentials for improvement, and respective reasons during the period under investigation. Thereby, they were encouraged to refer to example projects or customers. Having prepared workshop cards for the CRM processes where each card represented a process action, sales managers could also interactively highlight and comment on distinct process actions. We did not ask the interviewees directly for CSFs because it is known from research in information requirements determination that this may lead to unsatisfactory results more easily (Davis 1982). Each interview took between two and three hours and was attended by (always the same) two researchers. One of them led through the conversation, the other took notes. Each interview was recorded digitally in the case of prior permission.

Afterwards, the audio recordings were consolidated with the written notes. We used intentional analysis to analyze these protocols (Lacity and Janson 1994). The resulting lists of CSFs and additional qualitative information were sent to the respective sales managers for approval in order to offset unintentional bias (Patton 1990). Feedback and corrections were integrated. After all interviews had been conducted, a single joint list of CSFs was compiled for both SBTs where each CSF was assigned to one of the three perspectives. Although it was sometimes difficult to separate the organizational from the process perspective, we tried to find a clear assignment. CSFs that mainly involve sales representatives were assigned to the process perspective. CSFs that mainly concern over-arching issues or the interaction among different organizational units were assigned to the organizational perspective. Finally, the list was reviewed and approved by the project manager and the CRM process board (see next section).

4.2 Stage 2: Compiling CSF rankings for each SBT based on their degree of implementation

In this stage, questionnaire-based interviews were conducted. Each CSF was operationalized by several items, which were mainly derived from the qualitative information gathered in stage 1. In some existing studies, CSFs were directly compiled into questionnaires (Teo and Ang 1999; e. g. Somers and Nelson 2001). Our motivation for conducting an operationalization was to improve results by confronting the inter-viewees with concrete statements. The questionnaire contained closed-ended and open-ended items. The former were statements based on a 5-point Likert scale ranging from “I absolutely disagree” to “I absolutely agree” with either a positive or negative polarity. Open-ended items were used to gain additional qualitative in-depth insights. There were two types of open-ended items. As for the first type, interviewees could fill in arbitrary text. As for the second type, interviewees had to prioritize multiple given response options. Further options could be added. For some CSFs, only a few items were/could be derived. In some cases, there were only two including open-ended items. There were two reasons: First, the amount of time needed for filling in the questionnaire should be kept justifiable, but all CSFs should be included. Second, for some CSFs it was difficult to derive realistic items – even with the aid of the CRM process board. We admit that some CSFs should ideally have been operationalized by more closed-ended items. However, in the cases where only one closed-ended item was found we still provide a higher degree of concreteness than studies that directly compile CSFs into questionnaires. In addition, there is current research that advocates operationalizing constructs by single-item measures particularly for settings like ours where constructs are rather concrete, the sample size is limited, and actual behavior can be monitored only hardly (Fuchs and Diamantopoulos 2009). The closed-ended items are listed in Appendix A.

A draft version of the questionnaire was reviewed by the CRM process board and the project manager. Additionally, a pretest was conducted with the CRM process board. Based on the detailed feedback, some items were replaced or their wording changed. Items belonging to the same CSF were spread throughout the questionnaire. To enhance inter-interview consistency, instructions and FAQs for interviewees and interviewers were prepared.

In order to be consistent with stage 1, sales managers were selected as interviewees. At least one sales manager from each division and sales region should be interviewed. The selection policy was “learn from the successful”. The underpinning assumption was that there is a strong positive correlation between the degree to which a CSF is implemented by the sales representatives of a successful sales manager’s group – measured by the respective closed-ended items’ mean score – and the CSF’s contribution to run-time CRM success, e. g. sales success. This assumption has also been made by other studies, but only seldom explicitly (Sarker and Lee 2002). In order to identify successful sales managers for all divisions and sales regions – except for that where stage 1 had been conducted –, we had to ask the sales region managers as the highest sales management hierarchy level within a sales region (see Figure 1 (b)) for recommendations. This seemed to be the most reliable available indicator for several reasons: First, the company had no consistently implemented set of cross-SBT or -division performance indicators – particularly not on sales group level. Second, the sales managers’ self-estimation was supposed to be biased. Third, there were supposed to be additional non-monetary criteria characterizing a successful sales manager. All in all, 37 sales managers were interviewed (16 for “product sales” and 21 for “solution sales”). Each interview took between two and three hours and was attended by one researcher. This researcher answered the interviewees’ questions according to the FAQs and discussed open-ended items, which caused most of the interviews’ duration.

After all interviews had been conducted, the mean score and standard deviation (S. D.) were calculated for each CSF and SBT according to the closed-ended items and their polarity. Thereby, the lowest score was 1, the highest score was 5. Analogous to other studies (e. g. Somers and Nelson 2001), the rankings were compiled for each SBT and perspective on the foundation of descending mean scores. The standard deviation was only included if more CSFs had the same mean score. In such cases, the CSF with lower standard deviation was ranked better. Although we could have used other criteria such as a top two-box index, we relied on the mean score for two reasons: It is intuitive and has already been applied in multiple other studies (some are cited above). In order to analyze SBT-specific differences between CSF rankings, absolute rank differences – in the following often just rank differences – were calculated for each CSF by subtracting the respective SBT-specific ranks and using the absolute value. Finally, we point out that the rankings were compiled on two samples of 16 and 21 sales managers. It would certainly be inadequate to dogmatically stick to the rankings and mean scores up to the second decimal place – the more so as the standard deviation is not included by default. We would rather recommend interpreting the rankings as indications and stimuli for future work.

5 Findings and discussion

As a result of stage 1, operational CSFs were identified for each perspective. As a result of stage 2, CSF rankings were compiled for each perspective and SBT. All information is shown in Tab. IV-3, Tab. IV-4, and Tab. IV-5. Below, we discuss each CSF according to descending rank differences. We provide additional qualitative in-depth information if the questionnaire included open-ended items concerning the respective CSF. Finally, a brief synopsis is given.

5.1 Operational CSFs from the organizational perspective

Tab. IV-3 CSFs from the organizational perspective (ordered by decreasing mean score)

SBT “product sales”			**SBT “solution sales”**		
CSF	Mean	S. D.	CSF	Mean	S. D

					.
1. Long-term customer care by the same sales representative	4.31	0.92	1. Long-term customer care by the same sales representative	4.26	0.90
2. Continuous training of sales representatives	3.94	0.56	2. Direct headquarters contact persons for sales representatives	3.76	1.29
3. Back office assistance during proposal preparation	3.50	1.51	3. Project manager assistance during proposal preparation	3.52	1.43
4. Direct headquarters contact persons for sales representatives	3.38	1.73	4. Cross-divisional cooperation	3.38	1.25
5. Back office as customer contact point	3.34	1.31	5. Continuous training of sales representatives	3.26	0.98
6. Cross-divisional cooperation	3.22	1.35	6. Back office assistance during proposal preparation	3.16	1.41
7. Sales manager attendance at external customer calls	2.66	1.21	7. Sales manager attendance at external customer calls	3.14	1.17
8. Project manager assistance during proposal preparation	1.94	1.52	8. Back office as customer contact point	2.98	1.44

- *Project manager assistance during proposal preparation (Rank difference 5)*: The role of a project manager was said to depend on the SBT. As for “solution sales”, project managers usually worked for the headquarters and accounted for coordinating all activities from project hand-over to project close-out. As for “solution sales”, this CSF is ranked on position 3. Several reasons were given that justify involving the future project manager during proposal preparation: First, the project manager helps to mitigate technical and financial problems as well as to anticipate risks. Second, the proposed price is more realistic. Third, a trustful relationship between the project manager and the customer is established earlier. Fourth, less information is lost during project hand-over. As for “product sales”, project managers usually were sales managers who accounted for handling large product orders and tenders. For this SBT, the CSF is ranked on the last position.

- *Continuous training of sales representatives (Rank difference 3)*: “Product sales” managers stated that they send their sales representatives to 3.9 technical trainings and 1.7 sales trainings on average per year. “Solution sales” managers stated that they send their sales representatives to 3.1 technical trainings and 1.7 sales trainings on average per year. As for “product sales”, this CSF is ranked on position 2. As for “solution sales”, it is ranked on position 5.

- *Back office assistance during proposal preparation (Rank difference 3)*: Qualified assistance of the back office during proposal preparation was said to improve proposal quality, especially with respect to technical details. Moreover, sales representatives have more time for customer care. Sometimes, proposals are even compiled by the back office on its own. As for “product sales”, this CSF is ranked on position 3. As for “solution sales”, it is ranked on position 6.

- *Back office as customer contact point (Rank difference 3)*: The possibility for customers to directly contact the back office, e. g. in order to ask technical questions or to place simple orders, is ranked on position 5 for “product sales”. It was said to be essential that sales representatives and back office update each other regularly. As for “solution sales”, the CSF is ranked on position 8. Two reasons were given: First, sales representatives of “product sales” care for considerably more customers. Second, “product sales” orders are much less complex.

- *Direct headquarters contact persons for sales representatives (Rank difference 2)*: The main reason given for a direct contact to the headquarters was the opportunity for sales representatives to get better technical support. As for “product sales”, this CSF is ranked on position 4. As for “solution sales”, it is ranked on position 2.

- *Cross-divisional cooperation (Rank difference 2)*: In the case company, sales representatives could assign leads[1] to other divisions. This CSF is ranked on position 6 regarding “product sales” and on position 4 regarding “solution sales”. The main reason given for this low rank regarding “product sales” was the perceived poor quality of leads from other divisions. Moreover, the existing CRM system was barely

[1] In the CRM context, a lead represents a hint with low degree of maturity from inside or outside one’s division that refers to a potential customer or project opportunity.

used for exchanging leads. Most leads were exchanged directly and informally in the context of face-to-face communication or events (e. g. sales trainings).

- *Long-term customer care by the same sales representative (Rank difference 0)*: The fact that a sales representative cares for a customer for many years is the highest ranked CSF for both SBTs. “Product sales” mangers stated that their sales representatives care for their customers for 7 years on average and that new sales representatives need 12 months on average to get acquainted with customers, competitors, and the overall regional market. “Solution sales” managers stated that their sales representatives care for their customers for 6 years on average and that they need 10 months on average to get acquainted with customers, competitors, and the overall regional market.

- *Sales manager attendance at external customer calls (Rank difference 0)*: In some situations, sales managers accompanied their sales representatives to external customer calls. As for “product sales”, most sales managers did this on explicit demand only. “Product sales” managers stated to spend 20 hours, “solution sales” managers 7 hours per month on average at external customer calls. As for “solution sales”, the most important situations were order negotiations. This CSF is ranked on position 7 for both SBTs.

5.2 Operational CSFs from the CRM process perspective

Tab. IV-4 CSFs from the CRM process perspective (ordered by decreasing mean score)

SBT “product sales”			**SBT “solution sales”**		
CSF	Mean	S. D.	CSF	Mean	S. D.
1. Early technical involvement in calls for tenders	4.19	1.38	1. Topicality of order/project list	4.33	1.21
2. Active customer win-back	3.31	1.16	2. Consideration of win/loss analyses	4.24	0.90
3. Consideration of win/loss analyses	3.21	1.32	3. Early technical involvement in calls for tenders	4.10	1.17
4. Topicality of order/project list	2.69	1.65	4. Acquisition of new customers	3.14	1.42
5. Acquisition of new customers	2.31	1.16	5. Active customer win-back	3.00	1.07

6. Reports of external customer calls	2.22	1.24	6. Reports of external customer calls	2.12	1.05

- *Active customer win-back (Rank difference 3)*: In the case company, the most frequently taken measures for winning back customers were increase of visitation frequency and intensive conversations about the reasons for migration. Only in a few cases, sales representatives cut prices or adapted selling conditions (such as liability). As for “product sales”, this CSF is ranked on position 2. As for “solution sales”, it is ranked on position 5.

- *Topicality of order/project list (Rank difference 3)*: As for “solution sales”, this CSF is the highest ranked one. On average 78 % of the “solution sales” planned order volume were documented in order/project. As for “product sales”, the CSF is ranked on position 4. On average only 47 % of the “product sales” planned order volume were documented in order/project lists. The main reason given was that the demand for solutions is less predictable and thus requires more sophisticated planning. Therefore, the “solutions sales” representatives required the lists to contain not only topical orders/projects, but the entire sales funnel with orders/projects of different maturity levels.

- *Early technical involvement in calls for tenders (Rank difference 2)*: Sales representatives who technically counsel their customers prior to a call for tenders were said to be able to shift their customers’ needs towards the company’s portfolio. As for “product sales”, this CSF is the highest ranked one. Though sounding counter-intuitive at the first glance, the main reasons given were that huge product orders are almost exclusively assigned by tender and that tenders are a suitable opportunity to identify new customers. As for “solution sales”, this CSF is ranked on position 3.

- *Consideration of win/loss analyses (Rank difference 1)*: Considering the results of previous win/loss analyses was supposed to help constantly improving sales processes and customer intelligence. As for “solution sales”, this CSF is ranked on position 2. As for “product sales”, it is ranked on position 3. In the case company, win/loss analyses were mostly conducted on a single proposal basis. Lost proposals were analyzed more frequently than successful ones. Feedback interviews with both the involved proposal team and single sales representatives were held for analyzing purposes.

- *Acquisition of new customers (Rank difference 1)*: For both SBTs, this CSF is ranked low, i. e. position 5 regarding “product sales” and position 4 regarding “solution sales”. Sales representatives spent on average 10 % of their working time identifying new customers. The indicated reason was that due to area-covering sales many divisions believed to know most (potential) customers. New customers were mainly identified by own market analyses, but also by tenders and by data of external providers.

- *Reports of external customer calls (Rank difference 0)*: By using reports of external customer calls, it was supposed to be easier for sales representatives and managers to prepare for future customer calls. However, this CSF is ranked on the last position for both SBTs. The indicated reason was that creating such reports mainly causes additional effort. Reports were created for very large projects only.

5.3 Operational CSFs from the information requirements perspective

Tab. IV-5 CSFs from the information requirements perspective (ordered by decreasing mean score)

SBT “product sales“			**SBT “solution sales“**		
CSF	Mean	S. D.	CSF	Mean	S. D.
1. Knowledge of the portfolio elements that customers obtained from competitors	4.25	0.79	1. Knowledge of the customers’ business and production processes	4.38	0.79
2. Knowledge of customer satisfaction	4.16	0.83	2. Knowledge of the customers' placing strategy and criteria	4.17	0.65
3. Knowledge of the customers' placing strategy and criteria	4.09	0.91	3. Knowledge of customer satisfaction	4.17	1.02
4. Knowledge of the customers’ business and production processes	4.09	1.23	4. Knowledge of the customers' business strategy	3.92	0.93
5. Knowledge of the customers' competitors	3.78	1.11	5. Knowledge of the customers’ corporate structure	3.90	1.15

6.	Knowledge of the customers' customers	3.75	1.09	6.	Knowledge of the portfolio elements that customers obtained from competitors	3.81	0.88
7.	Knowledge of the customers' business strategy	3.75	1.16	7.	Knowledge of other divisions' portfolio elements	3.57	1.09
8.	Profound technical knowledge of own portfolio elements	3.75	1.30	8.	Knowledge of the customers' competitors	3.64	1.21
9.	Knowledge of the customers' corporate structure	3.69	1.04	9.	Profound technical knowledge of own portfolio elements	3.29	1.25
10.	Knowledge of other divisions' portfolio elements	2.69	1.33	10.	Knowledge of the customers' customers	3.29	1.55

- *Knowledge of the portfolio elements that customers obtained from competitors (Rank difference 5)*: Sales representatives knowing which portfolio elements customers obtained from competitors were said to be able to advise customers on how to complement / replace these portfolio elements with own ones. As for “product sales”, this CSF is the highest ranked one. As for “solution sales”, it is ranked on position 6. In addition, sales representatives wanted to know which own portfolio elements are installed and what is the economic potential of own portfolio elements not installed so far. “Product sales” representatives additionally needed product reselling cycles, i. e. the number of years after which products usually need to be replaced.

- *Knowledge of the customers' customers (Rank difference 4)*: Knowing the needs of the customers’ customers was said to help sales representatives to better understand their own customers’ needs. As for “product sales”, it is ranked on position 6. As for “solution sales”, it is the lowest ranked CSF.

- *Knowledge of the customers’ corporate structure (Rank difference 4)*: “Product sales” managers stated that their sales representatives on average know the corporate structure of 80 % of their customers and spend on average 2.4 hours per month maintaining it. In this sense, maintaining means updating the corporate structure stored in the CRM system(s). The CSF is ranked on position 9 for “product sales”. As for “solution sales”, it is ranked on position 5. Respective sales managers stated that their sales representatives on average know the corporate structure of 76 % of their customers and spend on average 4.3 hours per month maintaining it.

- *Knowledge of the customers' business and production processes (Rank difference 3)*: As for "product sales", this CSF is ranked on position 4, whereas for "solution sales" it is the highest ranked CSF.

- *Knowledge of customers' competitors (Rank difference 3)*: Sales representatives who know the customers' competitors and their portfolio were said to be able to demonstrate the competitive advantage customers can attain by the case company's portfolio. As for "product sales", this CSF is ranked on position 5. As for "solution sales", it is ranked on position 8.

- *Knowledge of the customers' business strategy (Rank difference 3)*: Knowing in which projects customers want to invest in the next years as well as knowing the portfolio customers want to offer in the next years was said to help sales representatives to better understand their customers' needs. As for "product sales", this CSF is ranked on position 7. As for "solution sales", it is ranked on position 4.

- *Knowledge of other divisions' portfolio elements (Rank difference 3)*: As for "product sales", this CSF is ranked on the last position. As for "solution sales", it is ranked on position 7.

- *Knowledge of customer satisfaction (Rank difference 1)*: This CSF is ranked on the second position for "product sales" and on position 3 for "solution sales". In the case company, customer satisfaction was mainly determined by standardized surveys, informal conversations during regular external calls, and conversations after project close-out. External service providers were used only seldom. It was said that sales representatives address the topic of customer satisfaction on average in a quarterly or yearly interval.

- *Knowledge of the customers' placing strategy and criteria (Rank difference 1)*: As for "product sales", this CSF is ranked on position 3. As for "solution sales", it is ranked on position 2. The customers' most relevant criteria for vendor selection were said to be the personal relation between customer and sales representative, technical functionality, and price.

- *Profound technical knowledge of own portfolio elements (Rank difference 1)*: For both SBTs, this CSF is ranked low. As for "product sales", it is ranked on position 8. As for "solution sales", it is on ranked the second last position.

5.4 Synopsis

For each perspective, we identified operational CSFs and compiled SBT-specific rankings. In the case company, there are eight CSFs for the organizational perspective, six for the process perspective, and ten for the information requirements perspective. By analyzing the rank differences within each perspective, it becomes evident that there are differences and commonalities between the SBTs. In other words, there are CSFs with a high rank difference and others with low rank difference. Examples for the first category are "Project manager assistance during proposal preparation" (Rank difference 5) for the organizational perspective and "Knowledge of the portfolio elements that customers obtained from competitors" (Rank difference 5) for the information requirements perspective. Examples of the second category are "Long-term customer care by the same sales representative" (Rank difference 0) for the organizational perspective and "Reports of external customer calls" (Rank difference 0) for the process perspective. We also observed that there are approximately equally strong differences between the SBTs regarding each perspective[2]. In other words, there is no perspective for which the CSFs are ranked almost identically.

In order to achieve an overall understanding of operational CSFs, we also compiled a cross-SBT ranking for each perspective (see Appendix B). From an organizational perspective, the top three CSFs are "Long-term customer care by the same sales

[2] One possibility to check this property is to calculate the quotient of the actual cumulated rank difference and the highest possible cumulated rank difference for each perspective. On the foundation of the rankings presented above, this quotient is approximately 0.56 for each perspective.

representative”, “Direct headquarters contact persons for sales representatives”, and “Continuous training of sales representatives”. From the process perspective, the top three CSFs are “Early technical involvement in calls for tenders”, “Consideration of win/loss analyses”, and “Topicality of order/project list”. Finally, from the information requirements perspective, the top three CSFs are “Knowledge of the customers’ business and production processes”, “Knowledge of customer satisfaction”, and “Knowledge of the customers' placing strategy and criteria”.

6 Summary, Limitations, and Implications

With this paper, we intended to provide preliminary in-depth knowledge about operational CRM-related CSFs with respect to organizational setting, CRM process, and information requirements from a sales representative’s point of view. We therefore reported the results of a descriptive single-case study conducted at the German sales department of a globally acting company from the electronics and electrical engineering industry. In addition, we analyzed the differences and commonalities of the case company’s two top-selling SBTs “product sales” and “solution sales”. Though leading to valuable results, this case study has some limitations:

- *Restricted generalizability*: In general, single-case studies provide only restricted grounding for generalization. Despite the descriptive nature of this case study, the findings are at best conferrable to companies with a similar organizational macro-structure, i. e. where sales departments address business customers by area-covering direct sales and where SBTs similar to “product sales” and “solution sales” exist – not necessarily both SBTs at the same time. Though knowing that CRM is a wide subject, we exclusively focused on sales departments and a sales representative’s point of view. Other roles from the sales management hierarchy as well as marketing and service departments were excluded deliberately. Admittedly, this is a restricted scope. There were two reasons for accepting this restriction: First, the case study should be focused. Second, we aimed at extending current knowledge by operational CSFs, which only seemed feasible by sticking to a restricted scope.

- *Methodological drawbacks*: Due to the complex social setting and the fact that the behavior of involved people could not be controlled as in an experimental setting, some methodological drawbacks were inevitable. The in-depth insights into the so far relatively unstructured phenomenon of operational CRM-related CSFs may serve as compensation. We unveil the drawbacks so that scholars and practitioners will better know how to treat the findings: First, selecting suitable interviewees was complicated by the fact that sales success could not be operationalized. The reason was that the company had no consistently implemented performance indicators. Due to potential bias, we also refrained from using the sales managers' self-evaluation. The most reliable available indicator seemed to be the judgment of the sales region managers. These, however, were only willing to nominate successful sales managers, a circumstance detaining us from counter-checking the CSFs' degree of implementation with less successful sales managers. Consequently, the identified CSFs have a low level of criticality according to the taxonomy of Williams and Ramaprasad (1996). They are associated with success in the sense of coincident appearance. Second, some CSFs may not have been operationalized by as many closed-ended items as desirable (see discussion above). A drawback was that most CSFs have not been studied yet so that there was no literature to which we could have reverted. However, in cases where only one closed-ended item was found we still provide a higher degree of concreteness than studies that directly compile CSFs into questionnaires and thus completely omit operationalization.

Despite the limitations, practitioners may ask for managerial implications. Due to the descriptive nature of this case study, we may not give direct recommendations based on the identified CSFs. What we can do instead is reporting what measures the case company took or intended to take for implementing the CSFs. With all due care, this may provide valuable hints for further action and thus benefit other companies:

- *Implementation of a role-based CRM system*: In order to support information requirements CSFs and process CSFs, the company intended to implement a role-based CRM system. A role was defined for each SBT. The CRM system's functionality and the information provided were customized accordingly. This should help to spare sales representatives unnecessary complexity. When using the CRM system, sales representatives just had to indicate the SBT for which they wanted to work.

- *Specification of a CRM process handbook*: The company planned to specify a normative process handbook that should integrate existing CRM processes and SBT-specific process CSFs. Subsequent interviews were supposed to disclose additional insights into process actions. This should help to make sales representatives familiar with SBT-specific particularities and to ensure that CSF-relevant process actions are considered more intensively in daily sales business.

- *Evolution of the sales training program*: As another measure, the company intended to evolve its sales training program. First, training modules were to be developed for each SBT, which take process CSFs and information requirements CSFs into account. Second, sales representatives were supposed to undergo regular assessments in the sense of a knowledge gap analysis. Based on the knowledge of individual strengths and weaknesses, this should help to individualize each sales representative’s training program.

- *Prioritization of CSFs*: Finally, the case company estimated that it would not be economically reasonable to implement CSFs by simply following an “all-or-nothing” or “the-more-the-better” policy. The main reason was that beyond some degree of implementation the costs for implementing an additional CSF were supposed to justify the respective value added no longer – apart from the fact that allocating value added to single CSFs is difficult by itself (Leidecker and Bruno 1984). In addition, the amount of implementable CSFs was limited by budget restrictions. Thus, the company prioritized CSFs and planned to implement them both selectively and subsequently. Thereby, the rankings from above were useful.

Apart from managerial implications, there are theoretical implications that stimulate further research. According to Williams and Ramaprasad (1996), the value of explicating factors with a low level of criticality is that these factors trigger a closer examination of the causal mechanisms at work. The CSFs presented above may thus be seen as a first step. One possibility of deepening knowledge consists in conducting further case studies – particularly in multiple-case settings (Yin 2009) – until a more mature foundation for generalization and inductive theory-building has been compiled (Eisenhardt 1989; Carroll and Swatman 2000). Such multiple-case studies may be conducted in companies both similar and different to the case company. They could also incorporate additional aspects such as moderating variables (e. g. company size, country, or industry as it has been done for enterprise software in general (e. g. Göbel et al. 2008)), different perspectives, points of view, and departments (e. g. marketing or service departments) as well as critical failure factors (if the necessary data can be made available). Finally, resultant theories may undergo empirical validation in order to further raise the theoretical level of knowledge about operational CRM-related CSFs, relevant to both today's scholars and practitioners implementing tomorrow's CRM (Dennis 2001).

Appendix A: Closed-ended items from the questionnaire

The following three tables present the closed-ended items from the questionnaire grouped by perspective and CSF. The open-ended items were omitted due to space restrictions. Therefore, the major findings were incorporated into the findings and discussion section.

Tab. IV-6 Closed-ended items for operational CSFs from the organizational perspective

ID	Item	Polarity
O1	**Back office as customer contact point**	
O1.1	The back office answers customer inquiries on behalf of my sales representatives.	+
O1.2	My sales representatives are the exclusive contact persons for their customers.	-
O2	**Long-term customer care by the same sales representatives**	
O2.1	My sales representatives care for their customers for many years.	+
O2.2	My sales representatives have a good personal relationship with their customers.	+
O3	**Back office assistance during proposal preparation**	
O3.1	The back office relieves my sales representatives of proposal preparation.	+

O3.2	My sales representatives prepare proposals almost exclusively on their own.	-
O3.3	The back office prepares proposals on its own.	+
O4	**Direct headquarters contact persons for sales representatives**	
O4.1	The headquarters helps my sales representatives directly by answering technical questions.	+
O4.2	My sales representatives don’t have direct contact persons in the headquarters.	-
O5	**Cross-divisional cooperation**	
O5.1	My sales representatives forward sales leads to other divisions regularly.	+
O5.2	My sales representatives systematically process sales leads received from other divisions.	+
O5.3	My sales representatives don’t receive sales leads from other divisions.	-
O5.4	Sales leads are almost exclusively exchanged before reporting deadlines.	-
O6	**Sales manager attendance at external customer calls**	
O6.1	I regularly accompany my sales representatives to external customer calls.	+
O6.2	I plan in detail and in advance which customer calls I will attend.	+
O7	**Project manager assistance during proposal preparation**	
O7.1	My sales representatives involve the future project manager during proposal preparation.	+
O8	**Continuous training of sales representatives**	
O8.1	My sales representatives regularly attend trainings regarding their sales skills.	+
O8.2	My sales representatives regularly attend trainings regarding their technical knowledge.	+

Tab. IV-7 Closed-ended items for operational CSFs from the CRM process perspective

ID	Item	Polarity
P1	**Acquisition of new customers**	
P1.1	My sales representatives currently maintain relations with all relevant customers.	-
P2	**Early technical involvement in calls for tenders**	
P2.1	My sales representatives consult customers technically before calls for tenders are published.	+
P2.2	My sales representatives react on calls for tenders without having been technically involved beforehand.	-
P3	**Active customer win-back**	
P3.1	My sales representatives systematically try to win lost customers back.	+
P4	**Consideration of win/loss analyses**	
P4.1	My sales representatives regularly start order preparation processes from scratch.	-
P4.2	My sales representatives don’t conduct win/loss analyses of previous order preparation processes.	-

P4.3	My sales representatives consider previous win/loss analyses in daily sales business.	+
P5	**Topicality of order/project list**	
P5.1	Our planning process is substantiated by topical order/project lists.	+
P6	**Reports of external customer calls**	
P6.1	My sales representatives systematically create reports of external customer calls.	+
P6.2	I prepare for external customer calls with existing reports.	+

Tab. IV-8 Closed-ended items for operational CSFs from the information requirements perspective

ID	Description	Polarity
I1	**Knowledge of the portfolio elements that customers have obtained from competitors**	
I1.1	My sales representatives know what portfolio elements customers obtain from competitors.	+
I1.2	My sales representatives talk with their customers about how their installed base can be replaced or complemented with our portfolio elements.	+
I2	**Knowledge of customer satisfaction**	
I2.1	Customer satisfaction is an abstract expression and not relevant for our business.	-
I2.2	My sales representatives talk regularly with their customers about customer satisfaction.	+
I3	**Knowledge of the customers’ business and production processes**	
I3.1	My sales representatives know our customers’ business and production processes.	+
I3.2	My sales representatives have profound industry knowledge.	+
I4	**Knowledge of the customers' placing strategy and criteria**	
I4.1	My sales representatives know how customers place orders at our company or at competitors.	+
I4.2	My sales representatives know our customers’ contact persons and decision makers.	+
I5	**Knowledge of the customers' competitors**	
I5.1	My sales representatives know their customers’ top competitors.	+
I5.2	My sales representatives talk with their customers about how they can excel their competitors with our portfolio elements.	+
I6	**Knowledge of the customers' business strategy**	
I6.1	My sales representatives know in which products / projects our customers plan to invest.	+
I6.2	My sales representatives know what products and services our customers plan to offer.	+
I6.3	My sales representatives know how our customers develop their business strategy.	+
I6.4	My sales representatives don’t know our customers’ business strategy.	-
I7	**Knowledge of the customers' customers**	
I7.1	My sales representatives know the demand of their customers’ top customers.	+

I8	**Knowledge of the customers’ corporate structure**	
I8.1	We document our customers’ corporate structure in a central file.	+
I9	**Profound technical knowledge of own portfolio elements**	
I9.1	Our customers expect profound technical knowledge.	+
I9.2	My sales representatives have profound technical knowledge of our portfolio elements.	+
I9.3	My sales representatives usually ask headquarters contact persons in case of technical questions.	-
I10	**Knowledge of other divisions' portfolio elements**	
I10.1	My sales representatives know what their customers bought from other divisions.	+
I10.2	New sales representatives are trained with respect to other divisions’ portfolio elements.	+

Appendix B: Cross-SBT rankings for each perspective

The following three tables show the cross-SBT rankings for the perspectives under investigation.

Tab. IV-9 Cross-SBT ranking for the organizational perspective

CSF	Mean	S. D.
1. Long-term customer care by the same sales representative	4.28	0.91
2. Direct headquarters contact persons for sales representatives	3.59	1.51
3. Continuous training of sales representatives	3.55	0.89
4. Cross-divisional cooperation	3.31	1.30
5. Back office assistance during proposal preparation	3.31	1.46
6. Back office as customer contact point	3.14	1.40
7. Sales manager attendance at external customer calls	2.93	1.21
8. Project manager assistance during proposal preparation	2.84	1.67

Tab. IV-10 Cross-SBT ranking for the CRM process perspective

CSF	Mean	S. D.
1. Early technical involvement in calls for tenders	4.14	1.27
2. Consideration of win/loss analyses	3.79	1.22
3. Topicality of order/project list	3.62	1.63
4. Active customer win-back	3.14	1.12
5. Acquisition of new customers	2.78	1.38
6. Reports of external customer calls	2.16	1.14

Tab. IV-11 Cross-SBT ranking for the information requirements perspective

CSF	Mean	S. D.
1. Knowledge of the customers’ business and production processes	4.26	1.01
2. Knowledge of customer satisfaction	4.16	0.94
3. Knowledge of the customers' placing strategy and criteria	4.14	0.78
4. Knowledge of the portfolio elements that customers have obtained from competitors	4.00	0.87

5. Knowledge of the customers' business strategy	3.84	1.04
6. Knowledge of the customers’ corporate structure	3.81	1.11
7. Knowledge of the customers' competitors	3.70	1.17
8. Profound technical knowledge of own portfolio elements	3.49	1.29
9. Knowledge of the customers' customers	3.49	1.39
10. Knowledge of other divisions' portfolio elements	3.19	1.28

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V Fazit und Ausblick

In diesem Kapitel werden die zentralen Ergebnisse der vorgestellten Beiträge zusammengefasst und Ansatzpunkte für künftigen Forschungsbedarf aufgezeigt.

1 Fazit

Ziel dieser Dissertationsschrift war es, die Wissensbasis hinsichtlich der Phase Anforderungsanalyse im Rahmen der Entwicklung betrieblicher Anwendungssysteme für ausgewählte Anwendungssystemklassen weiterzuentwickeln. Dabei wurden verteilte Systeme (Kapitel II), Planungs- und Kontrollsysteme (Kapitel III) sowie operative Systeme (Kapitel IV) näher beleuchtet.

- In Kapitel II galt es, den Korrektheitsbegriff der formalen Verifikation für Web Service Kompositionen – als Beispiel für verteilte Systeme – zu konkretisieren und einen Anforderungskatalog für serviceorientierte Modellierungsansätze vorzuschlagen. Der Korrektheitsbegriff wurde auf Basis der allgemeinen Systemtheorie in struktur- und verhaltensorientierte Korrektheit unterteilt. Strukturorientierte Korrektheit fordert, dass Schnittstellenspezifikationen von Web Service Kompositionen und zu komponierenden Web Services mindestens bez. der Namen von Operationen sowie Anzahl, Reihenfolge und Datentyp von Parametern übereinstimmen. Verhaltensorientierte Korrektheit fordert, dass kontextunabhängige und -spezifische Verhaltensanforderungen eingehalten werden, die während der Anforderungsanalyse identifiziert wurden. Der Anforderungskatalog umfasst formale Syntax und Semantik als harte Anforderungen an die Spezifikation von Web Service Kompositionen und fachlichen Anforderungen. Als weiche Anforderungen an den Modellierungsprozess und dessen Systemunterstützung fordert er eine integrierte Modellierung von Web Service Kompositionen und fachlichen Anforderungen, ein entsprechendes Vorgehensmodell, Komplexitätsreduktion und Verhaltensvisualisierung durch Modellierungssoftware sowie konstruktive Hinweise durch Verfikationssoftware.

- Das Ziel von Kapitel III war es, den Kennzahlenauswahlprozess im Rahmen der Anforderungsanalyse für Planungs- und Kontrollsysteme unter der Annahme zu fundieren, dass Zusammenhänge zwischen Kennzahlen nicht über Funktionsgleichungen, sondern über Kontingenz- bzw. Korrelationskoeffizienten als Hilfsgrößen ausgedrückt werden. Im ersten Beitrag wurde der Kennzahlennutzen durch drei Komponenten spezifiziert: Nutzen durch statistischen Zusammenhang mit der Spitzenkennzahl, Nutzen durch statistischen Zusammenhang mit anderen Kennzahlen sowie Basisnutzen. Für die ersten beiden Komponenten gilt: Je stärker eine noch nicht gewählte Kennzahl mit anderen ebenfalls noch nicht gewählten Kennzahlen bzw. der Spitzenkennzahl statistisch zusammenhängt, desto mehr Nutzen stiftet sie. Hintergrund: Je stärker zwei Kennzahlen statistisch zusammenhängen, desto zuverlässiger kann die Ausprägung der einen bei Kenntnis der Ausprägung der anderen geschätzt werden – und mit desto weniger „Informationsverlust" kann innerhalb des Kennzahlennetzes auf eine der beiden Kennzahlen verzichtet werden. Der Basisnutzen dient der Quantifizierung von Kriterien wie z. B. Erhebungsaufwand, Interpretierbarkeit oder Beeinflussbarkeit. Zudem wurde ein zweistufiger Auswahlalgorithmus vorgeschlagen. Im ersten Schritt werden Kennzahlen aussortiert, die einen festgelegten Mindestnutzen durch statistischen Zusammenhang mit der Spitzenkennzahl unterschreiten. Im zweiten Schritt werden auf Basis einer Greedy-Heuristik und einer exogen vorgegebenen Maximalanzahl die Kennzahlen ausgewählt, die gemeinsam möglichst stark mit anderen Kennzahlen zusammenhängen und möglichst hohen Basisnutzen stiften. Die Gewichtung beider Nutzenkomponenten kann dabei im Vorfeld festgelegt werden. Im zweiten Beitrag werden Basisnutzen und Nutzen durch statistischen Zusammenhang mit der Spitzenkennzahl ausgeblendet. Dafür werden die „willkürlich" vorgegebene Maximalanzahl und die Greedy-Heuristik durch eine Trade-Off Betrachtung von informationellen und ökonomischen Zielen ersetzt. Anhand eines Optimierungsmodells wird somit bestimmt, welche und wie viele Kennzahlen hinsichtlich der informationellen und ökonomischen Ziele optimalerweise auszuwählen sind.

- In Kapitel IV galt es, anhand einer Fallstudie erste Erkenntnisse über operative CRM-Erfolgsfaktoren aus den Perspektiven organisatorische Rahmenbedingungen, CRM-Prozess und Informationsbedarf aus dem Blickwinkel von Vertriebsbeauftragten zu identifizieren. Zudem sollten Unterschiede und Gemeinsamkeiten zwischen Produkt- und Lösungsvertrieb herausgearbeitet werden. Für die Perspektive organisatorische Rahmenbedingungen wurden acht Erfolgsfaktoren ermittelt. Die drei am stärksten umgesetzten sind „Langjährige Kundenbetreuung durch denselben Vertriebsbeauftragten“, „Direkte Ansprechpartner für Vertriebsbeauftragte im Stammhaus“ und „Kontinuierliche Weiterbildung von Vertriebsbeauftragten“. Für die Perspektive CRM-Prozess wurden sechs Erfolgsfaktoren identifiziert. Die drei am stärksten umgesetzten sind „Frühzeitige technische Einbindung bei Ausschreibungen“, „Berücksichtigung der Ergebnisse von Win-/Loss-Analysen im Vertriebsprozess“ und „Aktualität von Auftrags- und Projektlisten“. Für die Perspektive Informationsbedarf wurden zehn Erfolgsfaktoren ermittelt. Die drei am stärksten umgesetzten sind „Wissen über Geschäfts- und Produktionsprozesse der Kunden“, „Wissen über Kundenzufriedenheit“ und „Wissen über Vergabestrategien und -kriterien der Kunden“. Im Produkt- und Lösungsvertrieb weicht die Rangfolge der Erfolgsfaktoren in den einzelnen Perspektiven von der übergreifenden Rangfolge ab. Manche Erfolgsfaktoren werden im Produkt- und Lösungsvertrieb ähnlich stark umgesetzt, andere werden sehr unterschiedlich stark umgesetzt, was sich in unterschiedlichen Rangdifferenzen zeigt. Da die Erfolgsfaktoren u. a. im Rahmen semistrukturierter und fragebogenbasierter Interviews erhoben wurden, liegen für jeden Erfolgsfaktor qualitative Zusatzinformationen vor.

Abschließend lässt sich festhalten, dass die vorgestellten Beiträge die Wissensbasis zur Anforderungsanalyse für drei ausgewählte Anwendungssystemklassen weiterentwickeln. Darüber hinaus gibt es jedoch weitere Herausforderungen, die es künftig zu meistern gilt.

2 Ausblick

Im Folgenden werden für jede der untersuchten Anwendungssystemklassen Ansatzpunkte für zukünftigen Forschungsbedarf aufgezeigt:

- Der in Kapitel II vorgeschlagene Anforderungskatalog an serviceorientierte Modellierungsansätze kann u. a. in zweierlei Hinsicht erweitert werden:

1. Bislang wurde lediglich ein Modellierungsansatz anhand des Anforderungskatalogs analysiert und Erweiterungsbedarf aufgezeigt. Dies geschah vor dem Hintergrund einer basalen Evaluation, um die grundsätzliche Anwendbarkeit des Anforderungskatalogs zu zeigen. Eine umfassende Analyse mehrerer Modellierungsansätze und eine Identifikation des jeweiligen Erweiterungsbedarfs wären zwei sinnvolle nächste Schritte. Dies würde helfen, die Verifikation von Web Service Kompositionen stärker in bestehenden Modellierungsansätzen zu verankern und die Evaluation des Anforderungskatalogs auf eine breitere Grundlage zu stellen.

2. Der Anforderungskatalog umfasst derzeit (harte) Anforderungen an die Spezifikation von Web Service Kompositionen und fachlichen Anforderungen sowie (weiche) Anforderungen an den Modellierungsprozess und dessen Systemunterstützung. Gerade die harten Anforderungen führen zu zeitlichem und damit monetärem Zusatzaufwand. Der Grund ist, dass Web Service Kompositionen und fachliche Anforderungen formal spezifiziert, Korrektheit mittels Verifikation geprüft und Spezifikationen – mitunter mehrmals – angepasst werden müssen. Nicht für jeden Anwendungsfall ist jedoch im Vorfeld klar, ob der Zusatzaufwand die möglichen Schäden (z. B. aufgrund von SLA-Verletzungen) rechtfertigt. Um derartige Entscheidungen fundiert treffen zu können, bedarf es einer ökonomischen Analyse. Dazu müssten der erwartete Zusatzaufwand und die erwartete Schadenshöhe ggf. in Abhängigkeit von Anwendungsfall-Parametern (z. B. Komplexität des Anwendungsfalls) für eine spätere Trade-Off Betrachtung modelliert werden.

- Im Bereich der in Kapitel III vorgestellten Fundierung des Kennzahlenauswahlprozesses für Planungs- und Kontrollsysteme gibt es Forschungsbedarf u. a. hinsichtlich folgender fünf Punkte:

1. Das vorgeschlagene Optimierungsmodell wird bislang nur auf vorausgewählte Kennzahlen eines einzelnen Handlungsfelds angewandt. Mehrere Handlungsfelder können nur nacheinander und isoliert untersucht werden. Dadurch wird vernachlässigt, dass eine Kennzahl für die Steuerung mehrerer Handlungsfelder relevant

sein kann. Synergien bei der Berichtsgestaltung bleiben ungenutzt. Eine entsprechende Erweiterung des Optimierungsmodells sinnvoll.

2. Die bisherigen Beiträge konzentrieren sich im Sinne einer Reduktionsfragestellung auf die Auswahl einer Teilmenge bereits existierender Kennzahlen. Dies ist einerseits sinnvoll, da in vielen Unternehmen aufgrund historisch gewachsener Planungs- und Kontrollsystemlandschaften mehr Kennzahlen vorhanden sind als Entscheidungsträger jemals kognitiv verarbeiten können. Andererseits werden positive Effekte (zusätzlicher) innovativer Kennzahlen vernachlässigt. Letzteres wäre ein interessantes Feld für weitere Forschungsarbeiten.

3. Planungs- und Kontrollsysteme umfassen nicht nur Kennzahlen, sondern z. B. auch Dimensionen und Dimensionselemente. Bislang werden jedoch lediglich Kennzahlen betrachtet, wodurch u. a. zwei Problemfelder ausgeblendet werden: Zum einen wird die Multidimensionalität von Kennzahlen – also ihre Auswertbarkeit nach unterschiedlichen Dimensionen (z. B. Ort, Zeit, Produkt, Kunde) und ggf. hierarchischen Dimensionselementen (z. B. Niederlassung, Vertriebsregion, Land) – im vorgeschlagenen Optimierungsmodell nicht berücksichtigt. Zum anderen stellt sich analog zur Kennzahlenauswahl die Frage, welche Dimensionen bzw. Dimensionselemente unter Berücksichtigung informationeller und ökonomischer Zielen ausgewählt werden sollten. Im Rahmen einer ganzheitlichen Betrachtung von Planungs- und Kontrollsystemen darf es daher nicht bei einer Untersuchung des Kennzahlenauswahlprozesses bleiben.

4. Das vorgestellte Optimierungsmodell wurde erfolgreich auf der Basis realer Daten angewandt. Nichtsdestotrotz fehlt empirische Evidenz, ob die Empfehlungen tatsächlich die Entscheidungsqualität verbessern. Gemeint ist damit insbes. die Qualität der Entscheidungen, die Entscheidungsträger auf Basis der ausgewählten Kennzahlen treffen. Hier gilt es, ein geeignetes Evaluationsrahmenwerk zu entwerfen und empirische Studien durchzuführen.

5. Im zweiten Beitrag werden statistische Zusammenhänge zwischen Kennzahlen aus dem Kennzahlennetz und der Spitzenkennzahl bewusst ausgeblendet, um das Optimierungsmodell unter vereinfachenden Annahmen zu formulieren. Diese

Zusammenhänge sind im Rahmen weiterer Forschungsarbeiten wieder aufzugreifen. Zum einen weil sich hier ein weiterer Trade-Off auftut. So können manche Kennzahlen stark mit anderen Kennzahlen und schwach mit der Spitzenkennzahl zusammenhängen, andere dafür schwach mit anderen Kennzahlen und stark mit der Spitzenkennzahl. Darüber hinaus ist jede „Graustufe" vorstellbar. Zum anderen weil der Spitzenkennzahl im Rahmen der Unternehmensführung besondere Bedeutung zukommt. So stellt sich z. B. vor dem Hintergrund der wertorientierten Unternehmensführung konkret die Frage, wie Handlungsfelder (z. B. Unternehmensbereiche) kompatibel zum Ziel der Unternehmenswertsteigerung dauerhaft oder transitorisch auf der Basis statistischer Zusammenhänge als Hilfsgrößen gesteuert werden können, wenn geeignete ertrags-/risikoorientierte Kennzahlen fehlen, deren Einführung längeren Vorlaufs bedarf oder ökonomisch nicht sinnvoll ist.

- Die in Kapitel IV identifizierten operativen CRM-Erfolgsfaktoren sind lediglich ein erster Schritt zu einem vertieften Verständnis. Dies hat mehrere Gründe: Zum einen bieten Einzelfallstudien nur eine eingeschränkte Basis für Verallgemeinerung. Zum anderen ist Fallstudien trotz z. T. aufwendiger Qualitätssicherungsmaßnahmen ein gewisses praxeologisches Element inhärent, was insbes. am komplexen soziotechnischen Umfeld und der – im Gegensatz zu Laborexperimenten – mangelnden Kontrollierbarkeit externer Einflussgrößen liegt. Nichtsdestotrotz dienen die identifizierten Erfolgsfaktoren als Impuls für weitere Forschungsarbeiten. Dies können zunächst weitere Fallstudien sein. Diese wären idealerweise als multiple Fallstudien durchzuführen und könnten moderierende Variablen (z. B. Unternehmensgröße, Land oder Wirtschaftszweig) oder andere Analyseeinheiten (z. B. Marketing- und Servicebereiche) untersuchen. Ziel wäre es, eine breitere Basis für Verallgemeinerung und induktive Theoriebildung zusammenzustellen. Die so entstehenden Theorien könnten anschließend empirischer Validierung unterzogen werden und als Ausgangspunkt für die Gestaltung nützlicher IT-Artefakte dienen.

In dieser Dissertationsschrift wurden nur einzelne Aspekte vertiefend betrachtet. Künftig gilt es, die Forschung im Bereich der Anforderungsanalyse für die hier untersuchten wie auch für weitere Anwendungssystemklassen voranzutreiben. Dabei können die vorgestellten Beiträge einen Ausgangspunkt darstellen. Des Weiteren bieten die anderen Phasen der Anwendungssystementwicklung und die Querschnittsaufgaben (z. B. Projektmanagement oder Qualitätsmanagement) eine Vielzahl unerforschter Fragestellungen mit Bedeutung für die Wirtschaftsinformatik.